DAILY HETEROGENEITY IN HABITAT SELECTION BY THE PORCUPINE CARIBOU HERD DURING CALVING

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Abstract

Caribou exhibit scale-dependent habitat selection, but variance in daily habitat selection by the Porcupine Caribou Herd (PCH) has not been examined. Investigating temporal variance in habitat selection may clarify the time period when managers may accurately estimate calving-related habitat selection. Annually, 1992-1994, approximately 70 calves were radio-collared within 2 days of birth and relocated daily until departing the calving grounds. We used daily 99% fixed kernel utilization distributions (UD's) to estimate caribou distributions, then estimated daily habitat selection using logistic regression. Habitat variables included relative vegetation greenness, greening rate, landcover class, and elevation. Spatial scales of investigation included concentrated vs. peripheral use within daily UD's, daily use within the merged extent of all daily UD's, and daily use within the historical extent of calving, 1983-2001. We used linear regression of logistic regression parameter estimates on sequential sampling days to estimate temporal habitat selection trends during the 3 weeks following capture. Overall, caribou exhibited habitat selection at multiple scales, without temporal trends, suggesting that the 21-day period following capture constituted a single domain and that managers may accurately estimate calving-related habitat selection at any point during this period.

Table of Contents

List of Figures

List of Tables

List of Appendices

Introduction

Scale is an important concept in ecology, and it has two components: grain and extent. Grain is the resolution of data measurement, and extent is the temporal or spatial scope of interest in a study (Wiens 1989). When the basis of performance or behavior of an animal is consistent over a spatial region or period of time, then that area or time frame constitutes a domain (Wiens 1989). A domain may consist of one or more scales, and it should be defined by the animal's behavior rather than by arbitrary definition. To estimate a domain, biologists should use available, pertinent data to maximize the usefulness and relevance of an investigation.

As the mechanistic basis of habitat selection changes, animals may exhibit changing selection patterns (O'Neill and King 1998). For example, as an animal meets nutritional requirements, we may expect the basis of habitat selection to change as the relative importance of other mechanisms such as predator or parasite avoidance increases. Accordingly, caribou may respond to habitat attributes differently at different temporal and spatial scales (White et al. 1975; White and Trudell 1980; Griffith et al. 2002). Habitat selection studies should address this possibility by investigating multiple animal-defined scales (O'Neill and King 1998; Wiens 1989). Examining temporal variation in selection by caribou addresses the importance of temporal scale in habitat selection studies, and our investigation of daily selection will augment previous, longer

temporal scale habitat selection studies of the Porcupine Caribou Herd (PCH) (Griffith et al. 2002).

Estimating calving distributions of barren ground caribou herds can be difficult. Due to the high costs of flight time, fuel, manpower, and logistical support, field operations in the Arctic and sub-Arctic can be quite expensive, and unpredictable flying weather can effectively prohibit field operations for several days at a time. Understanding temporal selection patterns of caribou during and following calving may increase confidence in estimates of calving-related habitat selection by quantifying the temporal consistency of selection.

In 2001, North American caribou biologists standardized the definition of calving grounds as "the area occupied by the parturient barren-ground caribou from calf birth through the initiation of foraging by calves" and agreed that calves can be considered foragers at 3 weeks of age (Russell et al. 2002). Further, the calving period was defined as the time of year when caribou use the calving grounds (Russell et al. 2002). Our purpose was to test the hypothesis that the 21-day period following parturition constituted a single biologically relevant domain for caribou. To address this issue, we developed three objectives:

1) to estimate habitat selection on each day during calving at multiple spatial scales,
2) to estimate habitat selection trends during calving, and
3) to estimate overall habitat selection during the calving period.

Chapter 1. DAILY HETEROGENEITY IN HABITAT SELECTION BY CARIBOU DURING CALVING[1]

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DAILY HETEROGENEITY IN HABITAT SELECTION BY CARIBOU DURING CALVING

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Abstract: Caribou (*Rangifer tarandus*) exhibit scale-dependent habitat selection, but previous studies of the Porcupine Caribou Herd (PCH) have not examined

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variance in daily habitat selection after calving. Investigating temporal variance in habitat selection by the PCH may elucidate temporal selection patterns while clarifying the time period when managers may accurately estimate calving-related habitat selection. In 1992-1994, approximately 70 calves were radio-collared annually within 2 to 3 days of birth and relocated daily until they died or departed the calving grounds. We used daily 99% fixed kernel utilization distributions (UD's) and historical records to estimate the spatial scales of calving caribou. Within these spatial scales, we estimated daily habitat selection using logistic regression. Habitat variables included relative vegetation greeness, greening rate, landcover class, and elevation. Spatial scales of investigation included concentrated vs. peripheral use within daily UD's, daily use within the aggregate UD (merged extent of all daily UD's), and daily use within the historical extent of calving (merged extent of all annual calving grounds, 1983-2001). At the daily utilization distribution scale, we built daily logistic regression selection models contrasting calf locations in concentrated use areas (CUA's) with calf locations in the UD periphery. At the aggregate utilization distribution and historical extent of calving scales, we contrasted calf locations with random available points. We used linear regression of logistic regression parameter estimates on sequential sampling days to estimate temporal habitat selection trends. Overall, caribou exhibited habitat selection at the multiple spatial scales and did not display temporal trends in selection during the 21 days post-capture,

suggesting that this period constituted a single biological domain within which manages may accurately estimate calving-related habitat selection.

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Key words: Arctic National Wildlife Refuge, calving, caribou, habitat selection, logistic regression, reproduction, scale, spatial, temporal

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A domain is a spatial region or period of time over which we may expect the basis of performance or behavior, such as survival or habitat selection, to be consistent (Wiens 1989). As the mechanistic basis of habitat selection changes, animals may exhibit different selection patterns (O'Neill and King 1998). For example, as an animal meets nutritional requirements, we may expect the basis of habitat selection to change as the relative importance of other mechanisms such as predator or parasite avoidance increases.

In an ecological context, scale consists of grain and extent (Wiens 1989). Grain is the resolution of data measurement, and extent is the spatial or temporal scope of interest in a study (Wiens 1989). Previous studies show that the basis of selection by caribou may alternate successively between forage digestibility and forage biomass as spatial scale changes (White et al. 1975; White and Trudell 1980; Griffith et al. 2002). Accordingly, caribou may respond to habitat attributes differently at different temporal and spatial scales. Habitat selection studies should address this possibility by investigating multiple animal-defined scales (Wiens 1989; O'Neill and King 1998).

Examining temporal variation in selection within caribou-defined spatial scales addresses the importance of scale in habitat use and selection studies, and our investigation of daily selection augments previous, longer temporal scale habitat selection studies of the Porcupine Caribou Herd (PCH) (Griffith et al. 2002). Given the difficulty weather and logistical constraints impose on estimating habitat selection during calving, managers could benefit from an increased understanding of the consistency of daily habitat selection after calving. Quantifying the temporal consistency of selection may increase confidence in calving-related habitat selection estimates.

The Porcupine Caribou Herd (PCH) ranges over an area of approximately 290,000 km^2 in Canada and Alaska and migrates each year between calving grounds on the arctic coastal plain and wintering areas in the boreal forests of the Yukon Territory and Alaska (Russell at al. 1993; Griffith et al. 2002). For the remainder of this paper, we refer to the Porcupine Caribou Herd by the acronym PCH. Parturient cows arrive on the calving grounds in mid-May to early-June, and calving usually occurs during the first week of June (Russell at al. 1993; Griffith et al. 2002). Median calving dates in 1992, 1993, and 1994 were 31 May, 7 June, and 2 June, respectively (Griffith, unpublished data). Parturient cows moved a mean distance of approximately 2.5 km/day for the first seven days after birth during 1992-1994 (Griffith et al. 2002). During the second week after birth, that rate doubled to approximately 5 km/day, and it continued to increase through the fourth week after birth to 15-20 km/day (Griffith et al. 2002).

At different spatial scales, caribou may select different habitat characteristics. At calving, 1983-2001, parturient PCH females selected annual calving grounds with a higher rate of greening and less forage biomass than found in the historical extent of calving (Griffith et al. 2002). Within the annual calving grounds, parturient females selected concentrated use areas with high forage biomass, but there was no selection for greening rate at this scale (Griffith et al. 2002). These differences in selection at different spatial scales demonstrate the value of considering animal-defined scale in habitat selection studies.

In 2001, North American caribou biologists standardized the definition of calving grounds as "the area occupied by the parturient barren-ground caribou from calf birth through the initiation of foraging by calves" and agreed that calves can be considered foragers at 3 weeks of age (Russell et al. 2002). Further, the calving period was defined as the time of year when caribou use the calving grounds (Russell et al. 2002). Our purpose was to test this working hypothetical definition of the calving period (21 days post-calving) by quantifying the consistency of habitat selection patterns during this period. Our objectives were to estimate daily habitat selection during calving at multiple spatial scales, to test for persistent changes in the basis of selection (i.e., changes from selection to avoidance or vice versa), and to estimate prevailing selection patterns of an Alaskan subset of the PCH during the temporal domain defined by our data.

STUDY AREA

Caribou used the coastal plain of the Arctic National Wildlife Refuge in northern Alaska and the Yukon Territory for calving. The coastal plain lies between the crest of the Brooks Range and the Beaufort Sea, and several rivers and streams cross it. Vegetation is mostly tundra that includes dwarf shrubs, sedges, small herbs, lichens, and mosses. Landcover classes include wet sedge, moist sedge, herbaceous tussock tundra, shrub tussock, riparian, and non-vegetated (Jorgensen et al. 1994; Jorgensen at al. 2002). The Beaufort Sea coastline is dominated by narrow beaches, numerous points and spits, and various offshore features such as mudflats, barrier islands, and shoals (Clough et al. 1987). Five terrain types are common across in the study area: mountain terrain, foothill terrain, hilly coastal plains, river flood plains, and flat thaw-lake plains (Douglas et al. 2002). Summers are short and cool with frequent drizzle (Douglas et al. 2002). The average June temperature on the coast is 6 $^{\circ}$ C. A more complete description of the study area can be found in Clough et al. (Chapter 2, "Existing Environment" 1987).

METHODS

Each year, 1992-1994, approximately 70 caribou calves were captured within 2 to 3 days of parturition and fitted with VHF radio collars (Griffith et al. 2002). Available data included:

1) near-daily locations of 18-73 radio-collared calves during the first 3 weeks after birth, 1992-1994,
2) landcover map of the coastal plain of Arctic National Wildlife Refuge (ANWR) and the adjacent Yukon Territory (Jorgenson et al. 1994; Griffith et al. 2002),
3) digital elevation models of the north slope of Alaska and the Yukon Territory (Yukon Department of Renewable Resources 2000, Manley 2002),
4) a time series of remotely sensed vegetation index (Normalized Difference Vegetation Index or NDVI) (Griffith et al. 2002) on the coastal plain during each year, 1992-1994, and
5) historical extent of calving of the PCH (the merged extent of all annual calving grounds, as estimated by 99% fixed kernel utilization distributions (Silverman 1986; Seaman and Powell, 1996; Seaman et al. 1998, 1999; Worton 1989) of calving locations, 1983-2001 (Griffith et al. 2002)).

All calves in our sample were captured in Alaska following the perinatal period (the first 48 hours following birth). Ungulate neonates exhibit two dominant predator avoidance strategies: hiding or closely following their mother (Lent 1974). Caribou calves are "followers" (Lent 1974). In this paper, we refer to habitat selection by radio-collared calves, but this close association between

cows and their calves allows us to assume that selection by calves was indicative of selection by parturient cows.

Study Period. -- Two factors guided study period definition. First, the calving period was previously defined as the 21-day period following parturition (Russell et al. 2002), and we sought to test consistency of habitat selection during this perios. Second, we wanted to assure that sample sizes early in the study period were adequate for utilization distribution estimation (i.e., 20 to 30 animals; Silverman 1986; Seaman et al. 1999), and these sample sizes were not reached until two to three days after capture operations began.

Scales of Analysis. -- We estimated daily 99% fixed kernel utilization distributions (UD's) for collared calves using Least Squares Cross Validation in Kernel HR (Silverman 1986; Seaman and Powell 1996; Seaman et al. 1998, 1999; Worton 1989) during the study period, 1992-1994. Suggested minimum sample sizes for fixed kernel UD estimation range from 20 to 30 (Silverman 1986; Seaman et al. 1999), and we estimated daily UD's with 18 to 73 calf relocations. Daily concentrated use areas (CUA's) were defined as areas with greater than mean observation density (Seaman et al. 1998). The remainder of the daily UD comprised the UD periphery. An aggregate utilization distribution was estimated by merging all of the daily UD's from the 21-day study period. The historical extent of calving was the merged extent of annual calving grounds, 1983-2001 (Griffith et al. 2002).

We investigated selection by caribou at 3 animal-defined spatial scales of availability:

1) historical extent of calving, 1983-2001, clipped to the extent of the landcover class map (Jorgenson et al. 1994; Jorgensen et al. 2002; Griffith et al. 2002),
2) aggregate utilization distribution, and
3) daily 99% utilization distributions.

Approximately 65% of the historical extent of calving was encompassed by the landcover class map.

Relative Vegetation Greenness. -- Photosynthetically active radiation (PAR) falls within the wavelength range of 0.4 micrometers to 0.7 micrometers, and it is strongly absorbed by chlorophyll a, chlorophyll b, and carotenoids within photosynthetic leaves; conversely, light with wavelengths in the 0.7 to 1.3 micrometer range is strongly reflected by photosynthetic leaves (Tucker and Sellers 1986). Reflectance within both of these ranges can be measured using the advanced very high resolution radiometer (AVHRR) on board National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellites (Myneni et al. 1998; Griffith et al. 2002). Channel one on the AVHRR measures red reflectance in a wavelength range absorbed by photosynthetic vegetation (0.58 to 0.68 micrometers), and channel two measures near-infrared reflectance in a wavelength range reflected by photosynthetic vegetation (0.725 to 1.1 micrometers; Tucker and Sellers 1986; Myneni et al. 1998). These values are

used to calculate the NDVI as follows (Myneni et al. 1998): (channel 2 – channel 1) / (channel 2 + channel 1).

Normalized difference vegetation index (NDVI) values fall between -1 and 1, and photosynthetically active surfaces always have an NDVI value greater than 0 (Tucker and Sellers 1986; Myneni et al. 1998). Because there are positive, significant relationships between NDVI and above ground plant biomass in tundra, NDVI is useful estimator of differences in photosynthetic above ground plant biomass between areas within tundra (Hope et al. 1993). On the arctic coastal plain of Alaska and Canada, Griffith et al. (2002) used NDVI to estimate relative photosynthetic forage quantity, and NDVI rate of increase was used to estimate the accumulation of new, highly digestible photosynthetic tissue, which reflects forage quality.

To obtain daily estimates of NDVI, we used three cloud-free composite images of the North Slope of Alaska and the Yukon Territory. These composites were constructed using AVHRR data from NOAA satellites 11 and 12 and had a nominal resolution of one kilometer. Pixel values were the maximum NDVI value from a series of AVHRR images estimated during the following time periods:

1) as close as possible to the median calving date (29 May – 5 June)
2) approximately two weeks after the calving composite (10 June – 15 June)
3) early July (29 June – 8 July) (Griffith et al. 2002).

After eliminating large water bodies, we subjected these composites to a 3x3 low

pass mean filter to reduce potentially confounding effects of georeferencing inaccuracy. For each, there was a corresponding grid of each pixel value's associated Julian date. Grids of daily NDVI rate of increase were estimated between the composites, and these rate estimates were used with the NDVI composites to linearly interpolate daily NDVI values.

Elevation. -- Digital elevation models (DEM's) from Alaska (100 m resolution) and the Yukon Territory (90 m resolution) were used to obtain elevation estimates for calf re-locations and random points used in our analysis. Resolution was resampled to 30 m, and the DEM grids were merged to produce a seamless DEM that encompassed the historical extent of calving for the PCH, 1983-2001 (Manley 2002; Yukon Renewable Resources Geographic Information System).

Landcover Class. -- The 50 m resolution landcover class map of the coastal plain of the Arctic National Wildlife Refuge and the Northern Yukon was used to identify landcover class (Jorgenson et al. 1994; Griffith et al. 2002). The following classes were defined (Jorgensen et al. 2002; Griffith et al. 2002):

1) wet sedge,
2) moist sedge,
3) herbaceous tussock tundra,
4) shrub tussock tundra,
5) alpine,
6) riparian, and

7) non-vegetated.

This map was resampled to 1 km resolution using nearest neighbor methodology. Pixels in the 1 km resample were assigned the value of the original 50 m pixel that fell closest to the center of the one kilometer pixel. SAS (SAS Institute 2000) was used to create indicator variables for each landcover class listed above. For example, for the wet sedge indicator variable, all locations within 1 km wet sedge cells were assigned a wet sedge value of one while those not in wet sedge cells were given a value of zero.

Random Points. -- To estimate availability at the aggregate utilization distribution and historical extent of calving scales, we created random points in a GIS. Within the aggregate utilization distribution, we generated 100 random points per day in the study period. Within the historical extent of calving, we generated 200 random points per day in the study period.

Assigning Grid Values to Animal Locations and Random Points. -- We used a GIS to obtain values from each habitat attribute layer at each random point and animal location used in the analysis.

Estimating Median NDVI and Median NDVI Rate of Increase. -- Georeferencing inaccuracy and changing satellite platforms may introduce error into NDVI estimates (Griffith et al. 2002). To minimize the potential effects of these sources of error, we classed NDVI and NDVI rate of increase estimates as either:

1) above the median value, or

2) less than or equal to the median value.

Because our statistical analyses involved 3 spatial scales, NDVI and NDVI rate of increase median values were estimated at each spatial scale. Daily NDVI estimate grids and NDVI rate of increase grids were clipped to the following extents in order to determine median values at each scale:

1) the corresponding daily 99% UD,

2) the aggregate utilization distribution, and

3) the historical extent of calving, clipped to the extent of the landcover class map.

Median values of these clipped grids were then estimated using each grid's attribute table. We used SAS (SAS Institute 2000) to create binary variables where a value of 1 corresponded to estimates above the median and 0 corresponded to estimates less than or equal to the median.

Daily Models. -- Using design II, sampling protocol A from Manly et al. (2002), we modeled daily habitat use by radio-collared calves in comparison to approximately 200 random available points within the historical extent of calving, clipped to the extent of the landcover class map, and approximately 100 random available points within the aggregate utilization distribution. Unique sets of random points were used to estimate each daily model. At the daily utilization distribution scale, we modeled habitat use by radio-collared calves that were located in concentrated use areas in comparison to radio-collared calves that

were located in the daily UD periphery. This analysis does not match standard protocols described in Manly et al. (2002).

We used Proc Logistic in SAS (SAS Institute 2000) to analyze daily habitat selection at each spatial scale. Because of sample size limitations (Burnham and Anderson 2002), we only included landcover classes previously identified as important to the PCH during calving (Griffith et al. 2002). Logistic regression parameter estimates were estimated for all independent variables included in the model (Agresti 2002), so the logistic regression parameter estimates from our daily models would be comparable among days only if we included the same suite of variables in each model. In order to test for linear trends in these parameter estimates through time, we needed them to be comparable. Therefore, we built our daily models with a constant suite of variables that included:

1) wet sedge landcover class,
2) herbaceous tussock tundra landcover class,
3) NDVI,
4) NDVI rate of increase, and
5) elevation.

On the coastal plain, predator densities were highest in the foothills (i.e. above 300 m elevation; Young et al. 2002), but including an elevation based indicator variable for predation risk caused quasi-complete separation (QCS). Similarly, including an indicator variable for alpine landcover class (located in the

foothills and mountains) frequently caused QCS. Elevation, a continuous variable, was used as a combined surrogate for predation risk and the alpine landcover class to alleviate these modeling problems. Parameter estimates were calculated using maximum likelihood (SAS Institute 2000; Agresti 2002).

Analysis of Parameter Estimate Trends. -- To test the hypothesis that habitat selection was consistent throughout the 21-day calving period, we used Proc Reg in SAS (SAS Institute 2000) to estimate the relationship between each daily parameter estimate and Julian day, separately, by analysis scale, in each year.

Calving Period Models. -- We modeled habitat use by radio-collared calves throughout the 21-day period by building one logistic regression model each, at the historical extent of calving and at the aggregate utilization distribution scales, in each year. Annually, aggregate distribution and historical extent of calving scale models were built by contrasting approximately 1,000-1,200 daily radio-collared calf relocations with approximately 2,000 random available points within the aggregate utilization distribution and approximately 4,000 random available points within the historical extent of calving, clipped to the extent of the landcover class map, respectively. As a result of these larger sample sizes relative to the sample sizes in our daily selection models, all landcover classes could be included in these models. The variable Julian day was used to link daily use and availability.

All statistical tests were assumed significant at $\alpha < 0.05$. When evaluating significance of linear regression trend tests, we used Bonferroni procedures to provide experiment-wise error protection.

RESULTS

Daily Utilization Distributions and Concentrated Use Areas

Aggregate utilization distribution areas for the 21-day period were 6792 km^2, 5011 km^2, and 6489 km^2 for 1992, 1993, and 1994 respectively (Appendix A). In 1992, there was roughly a 40-fold difference in the smallest and largest daily 99% UD areas and a 128-fold difference in the smallest and largest CUA's (Table 1.1; Appendix B). CUA's accounted for 2.9 % to 16.7% of daily 99% UD area. In 1993, there was approximately a 9-fold difference in the smallest and largest daily 99% UD area and a 25-fold difference in the smallest and largest CUA's (Table 1.1; Appendix B). CUA's accounted for 1.9% to 10.9% of daily 99% UD area. In 1994, there was an approximately a 10-fold difference in the smallest and largest in daily 99% UD areas and an 84-fold difference in the smallest and largest CUA's (Table 1.1; Appendix B). CUA's accounted for 3.1% to 14.2% of UD area.

Logistic Regression Model Fit

Quasi-complete separation was the most frequent problem encountered while fitting logistic regression models, and it was usually caused by one independent binary variable with very few "1" level responses. Quasi-complete

separation was most common when comparing daily calf locations in the CUA with daily calf locations in the UD periphery, most likely because of the significantly smaller sample size at that spatial scale. Probably due to their non-uniform distribution across the landscape, wet sedge and herbaceous tussock tundra landcover classes were the variables most likely to cause quasi-complete separation at the daily utilization distribution scale. Quasi-complete separation and non-significant models were prevalent at the daily utilization distribution scale (Tables 1.2 -1.4). NDVI and NDVI rate of increase were classed above the median or less than or equal to the median, so they were more evenly distributed across the landscape. Because elevation is a continuous variable with numerous possible values across the landscape, it did not cause separation problems.

Quasi-complete separation only causes highly inaccurate parameter estimates and odds ratios for the parameter(s) causing separation (Allison 1999), so we did not alter daily models when it was detected (Tables 1.2-1.10). However, parameter estimates for the affected independent variables were excluded from subsequent linear regression analyses. Statistically non-significant models, combined with unreliable parameter estimates stemming from quasi-complete separation reduced sample size at the daily utilization distribution scale, so it was excluded from these and further analyses.

Daily Selection Models

Logistic regression parameter estimates were variable through the study period, in each year, and at each spatial scale (Tables 1.2-1.10; Appendix C).

Coefficients of variation for parameter estimates were large (Tables 1.11-1.13; Appendix C). Frequency of positive habitat variable parameter estimates in the daily selection models is summarized in Table 1.14.

Selection Trend Analysis

To account for dependence among the five habitat variable parameter estimates in our daily selection models, our Bonferroni-adjusted p-value for significance was 0.01.

1992. -- No habitat variables showed a significant selection trend through time at either spatial scale (Table 1.15).

1993. -- There was a significant positive trend in selection for NDVI rate of increase at the aggregate utilization distribution scale (r^2 = 0.414; Table 1.16). At the historical extent of calving scale, there were no significant trends in selection through time.

1994. -- No habitat variables showed significant trends in selection through time at either spatial scale (Table 1.17).

Only one of thirty linear regression tests for temporal selection trends was significant, and we expected one to two significant regressions by chance alone. Therefore, we concluded that there were no linear temporal trends in habitat selection during the calving period.

Calving Period Models

1992 Aggregate Utilization Distribution. -- Radio-collared calves selected high NDVI, high NDVI rate of increase, herbaceous tussock tundra and riparian

landcover classes (Table 1.18). They avoided wet sedge, moist sedge, shrub tussock tundra, and alpine landcover classes, and increasing elevation.

1992 Historical Extent of Calving. -- Radio-collared calves selected high NDVI, wet sedge, moist sedge, herbaceous tussock tundra, and riparian landcover classes (Table 1.18). They avoided high NDVI rate of increase, shrub tussock tundra and alpine landcover classes, and increasing elevation.

1993 Aggregate Utilization Distribution. -- Radio-collared calves selected high NDVI, high NDVI rate of increase, moist sedge, shrub tussock tundra, herbaceous tussock tundra, and riparian landcover classes (Table 1.18). They avoided increasing elevation, wet sedge and alpine landcover classes.

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1994 Aggregate Utilization Distribution. -- Radio-collared calves selected high NDVI, high NDVI rate of increase, herbaceous tussock tundra, shrub tussock tundra, and riparian landcover classes (Table 1.18). They avoided increasing elevation, wet sedge, moist sedge, and alpine landcover classes.

1994 Historical Extent of Calving. -- Radio-collared calves selected high NDVI, high NDVI rate of increase, moist sedge, herbaceous tussock tundra, shrub tussock tundra, and riparian landcover classes (Table 1.18). They avoided increasing elevation, wet sedge and alpine landcover classes.

We detected consistency in selection/avoidance among scales and years. Radio-collared calves selected high NDVI and herbaceous tussock tundra and riparian landcover classes in all models and high NDIV rate of increase in 5 of 6 models. High NDVI rate of increase was only avoided in 1992 at the historical extent of calving scale; this may have reflected the coastal plain's delayed green-up in 1992 that resulted from the presence of aerosols in the arctic from the 1991 Mt. Pinatubo eruptions (Stone et al. 1993). Radio-collared calves avoided alpine landcover class and higher elevation in all models and wet sedge landcover class in 5 of 6 models.

DISCUSSION

Throughout the growing season on Alaska's North Slope, NDVI values increase quickly initially, reach a peak, and then decline as vegetation begins to senesce in late July (Jia et al. 2004). Our 21-day study period fell within the sharp increase section of this curve, so linearly interpolating daily NDVI estimates between composites was a reasonably appropriate method for modeling relative above ground plant biomass and the accumulation of easily digestible new plant tissue. Daily heterogeneity in accumulation of degree days may have caused small temporal scale variance in pixel level NDVI that we could not detect.

Recent studies question the interpretation of logistic regression models in habitat selection studies with a used:available format (Keating and Cherry 2004).

If locations representing availability have a high probability of being used, biologists should not trust probabilities of use and odds ratio point estimates (Manly et al. 2002; Keating and Cherry 2004). Our study used logistic regression only to estimate habitat selection by radio-collared caribou calves and to compare the relative importance of those habitat variables. Because we did not predict the occurrence of caribou, our study did not violate these warnings.

Griffith et al. (2002) identified habitat variables important to caribou at calving over a 17-year period, and we sought to identify any changes in selection/avoidance of those variables during the calving period, within a 3-year subset. Because NDVI, NDVI rate of increase, herbaceous tussock tundra, and wet sedge were important over the 17-year time series, we chose them as model components *a priori*. Seventy-five percent of the daily utilization distribution scale models were significant (Tables 1.2-1.4). Eighty-one percent of the aggregate utilization distribution scale daily models were significant (Tables 1.5-1.7). One hundred percent of the daily selection models we fit using our forced suite of variables were significant (Tables 1.8-1.10).

Large variance in daily parameter estimates (Tables 1.11-1.13) and a tendency for those estimates to vary about zero (Tables 1.2-1.10) suggests that either,

1) daily sample sizes were not adequate to obtain precise parameter estimates,
2) there was a high degree of overlap in used and available locations, or

3) our suite of habitat variables did not include all habitat characteristics to which caribou responded.

Depending on year, we obtained an average of 52-64 daily relocations of radio-collared calves (Table 1.1). However, these relocations represented only 3%, 7%, and 5% of the daily 99% UD in 1992, 1993, and 1994, respectively. Because our relocations constituted such a small proportion of the daily 99% UD, they may not have precisely represented the area assumed used by radio-collared calves.

Daily UD's averaged 32%, 22%, and 35% of the aggregate utilization distribution, and 6%, 3%, and 6% of the historical extent of calving in 1992, 1993, and 1994, respectively. The better fit and concordance of larger scale models (Tables 1.8-1.10) may have indicated less overlap of use and availability, rather than greater strength of selection at the larger scale.

We may have improved our daily selection models by including estimates of daily predator distributions or weather variables, such as wind speed and temperature, that could index insect activity, but these data were not available. Classing NDVI and NDVI rate of increase as above or, less than or equal to, the daily median was necessary to deal with noise introduced by georeferencing inaccuracy and changing satellite platforms, but it probably reduced the explanatory power of these variables at a daily temporal scale.

We used logistic regression parameter estimates from our daily habitat selection models to investigate the consistency of habitat selection during

calving, and we considered the parameter estimate point estimates as the best representation of selection. Using the point estimates in our linear regression tests for trend violated the assumption that data points are relatively error free direct estimates, so we may have overestimated any linear trends that exist. While this increased our probability of detecting real linear trends, it also increased our probability of detecting false linear trends.

Of the 30 linear regression trend tests (Tables 1.15-1.17), we expected one or two significant regressions by chance alone. In our tests, one linear regression was significant. This, combined with the tendency of our method to overestimate linear trends by not accounting for parameter estimate error or serial correlation of parameter estimates from sequential days, suggested that there were, in fact, no linear trends in selection during the study period at any scale, in any year. The lack of linear trends in habitat selection supported the hypothesis that the pre-defined 3-week calving period (Russell et al. 2002) was a single temporal domain.

Other models, such as quadratic or cubic, may have fit the undulating pattern suggested by some of the plots of habitat variable parameter estimates vs. Julian day (Appendix C). For example, vegetation phenology advances through the calving period, and digestibility for a given landcover class peaks briefly with leaf-out and then declines. Accordingly, we might have expected quadratic patterns in selection for landcover classes through the calving period, but this pattern was not demonstrated in our data.

The putative undulating patterns may be a result of serial correlation. Non-independence of successive data points in a time series may result in underestimated standard errors, so any potential patterns in our data may be less pronounced than they appeared. Because these putative undulations did not result in large swings in parameter estimate values (i.e. shifts from selection to avoidance, or vice versa), they did not indicate inconsistent habitat selection.

Griffith et al. (2002) found that selection of forage quantity and quality alternated between successive spatial scales. We found that radio-collared calves selected both high forage quantity and high forage quality within the historical extent of calving but that selection for these habitat variables was weaker within the smaller aggregate UD scale. Maximizing access to both forage quantity and quality at the larger scale may have negated benefits of selection at the smaller scales. Alternately, we may have found weaker selection at the smaller scale because use:availability overlap was greater at the smaller compared to the larger scale. At this point, we cannot clearly tell which of the explanations for weaker selection at the smaller scale is most important.

There were differences between selection patterns in this study and those estimated by Griffith et al. (2002), and these differences may be partially attributed to methodological differences in the two studies. In this study, all radio-collared calves were at least 2 days old and were captured only in Alaska, so our sample only represented a geographic subset of the PCH calving distribution and did not include perinatal mortality. The UD's in Griffith et al.'s

(2002) study were estimated from calving locations in both Canada and Alaska, and their sample included calves who died within 48 hours of birth. Differences in our findings may indicate that habitat selection by cows that calved in Canada, cows that lost their calf to perinatal mortality, or both, differed from the subset of parturient cows in our sample in their habitat selection.

Our analysis was also limited to a 3-year subsample of the 17-year series included in Griffith et al. (2002). By comparing the medians of entire spatial scales (i.e. concentrated use areas, annual calving grounds, historical extent of calving), grain in that study was equivalent to the scales of interest (Griffith et al. 2002). At a much finer grain, we estimated the habitat characteristics of 1 km^2 pixels where radio-collared calves were located. As grain becomes finer, variance in measurement increases (Wiens 1989), and this increasing variance may have been reflected in our large CV's in parameter estimates. By increasing variance in our parameter estimates, our study's relatively finer grain made detecting selection and avoidance less likely; this could also account for differing results in the two studies. When combined, these issues make exact correspondence between the two studies unlikely.

NDVI and NDVI rate of increase parameter estimates at the historical extent of calving scale may have been biased by the limiting extent of our landcover class map. The landcover map we used did not cover the southern one-third to one-quarter of the historical extent of calving, which artificially limits the spatial extent of the historical extent of calving scale. Due to earlier green-up

in southern ranges, we would have expected the southern section of the historical extent of calving to have higher initial NDVI and lower NDVI rate of increase. This would have resulted in fewer available points falling on high NDVI and low NDVI rate of increase, potentially biasing our parameter estimates for these two variables at the historical extent of calving scale.

Even with these differences in methodology, both studies estimated selection for the same landcover classes, high forage biomass (high NDVI), and high forage digestibility (high NDVI rate of increase) (Griffith et al. 2002). We did not detect scale-dependent selection of high forage biomass and high forage digestibility, but this may have occurred because we used of our NDVI rate of increase estimates to obtain daily NDVI estimates. The resulting coupling of NDVI rate of increase with daily NDVI estimates may explain why we detected simultaneous selection of high NDVI and high NDVI rate of increase.

Selection for high NDVI and high NDVI rate of increase reflected the importance of forage quantity and forage quality to caribou during the calving period. Other studies also found that parturient caribou selected high forage quantity and quality (White et al. 1975; White and Trudell 1980; Wolfe 2000; Kellyhouse 2001). Energy requirements for lactating caribou are higher during the calving period than at any other time of year (White and Luick 1984). The recurrence of high forage quantity and quality as a theme in calving-related habitat selection may indicate that meeting the elevated energy requirements

associated with lactation is the basis of behavior for parturient barren ground caribou during calving.

Consistent negative parameter estimates for elevation (Tables 1.5 – 1.10) may have reflected avoidance of either high predation risk, alpine landcover class, or both. In the Arctic National Wildlife Refuge, predators are more likely to be encountered as elevation increases (Young et al. 2002). From 1983-2001, the population of PCH females avoided alpine vegetation when selecting annual calving grounds and concentrated use areas, which may have indicated avoidance of both predation risk and low forage quantity (Griffith et al. 2002). Although our parameter estimates for elevation were very close to zero, elevation was a continuous variable and must be considered in relation to the large range of elevations found in the historical extent of calving, clipped to the extent of the landcover class map. Within that extent, elevation varied between 0 m and approximately 1,000 m, so seemingly small elevation parameter estimates could have a large effect on the predicted probability that a point was a radio-collared calf location. Thus, consistently negative elevation parameter estimates may have indicated avoidance of predation risk and areas with low forage biomass.

Because we did not identify any consistent trends in selection during the three calving seasons in our study, we did not include time interaction terms in our overall 21-day logistic regression selection models. Consistent with our daily selection models, concordance was low for calving period models at the aggregate utilization distribution scale (Table 1.18). Calving period models at the

historical extent of calving scale correctly classified approximately 75 to 78% of all points.

The acceptable fit of our historical extent of calving scale models and relatively poor fit of our aggregate utilization distribution scale models (Tables 1.3-1.10) suggested that selection was strongest at the largest scale. Location of the annual calving grounds within the historical extent of calving may have maximized access to highly digestible forage biomass and preferred landcover classes; selection of locations within the annual calving grounds may not have conferred additional survival and/or calf-rearing benefits to parturient cows (Griffith et al. 2002). Alternatively, scale-dependent differences in model fit may have been a statistical artifact of the higher degree of overlap between used and available area at the aggregate utilization distribution scale, relative to the historical extent of calving scale.

Because it usually takes 3-5 days for managers to estimate calving locations and habitat selection by calves was free of temporal trends, calving-related habitat selection may be accurately estimated at any time during the 21-day calving period. However, sample timing could affect calf survival estimation. Locating cow/calf pairs later in the calving period eliminates cases of perinatal mortality from the sample, which biases calf survival estimation. If habitat selection differs between calves that survive and those that do not, locating cow/calf pairs later in the calving period could also affect habitat selection estimation.

MANAGEMENT IMPLICATIONS

We did not detect any persistent nor biologically interpretable, statistically significant temporal trends in habitat selection during the calving period, and this supported the contention that the calving period was a single biologically relevant temporal domain for caribou. We also found that parameter estimates from our daily habitat selection models varied about zero, and their coefficients of variation were large, indicating that daily habitat selection during this period may have been variable. Therefore, managers should be wary of concluding that habitat selection on any single day during the calving period is indicative of habitat selection throughout the entire calving period. Because it typically takes 3 to 5 days to locate the calving sites used to estimate annual calving grounds and habitat selection, the effect of day-to-day variance in habitat selection should be minimal and should not affect calving period habitat selection estimates.

The lack of temporal selection trends also suggested that calving-related habitat selection may be estimated at any point during the calving period. However, estimating habitat selection later in the calving period prohibits estimates of calving site location and calf survival because any calves who died earlier in the calving period are eliminated from the sample. This would also prevent managers from estimating the relationship between calf survival and habitat use. While we did not statistically address the movement of daily calf distributions (UD's) during the calving period, the range of movement of UD's

was relatively small compared to the area covered by the historical extent of calving.

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Table 1.1. Daily distributions and concentrated use areas. Areas were estimated from 99% fixed kernel analyses of radio-collared calves in Alaska, 1992-1994, from the Porcupine Caribou Herd.

	Area (km^2)								
Julian	1992			1993			1994		
Day	n[a]	CUA[b]	99% UD[c]	n	CUA	99% UD	n	CUA	99% UD
155	23	27	327	67	61	849	63	236	2,813
156	N/A[d]	N/A	N/A	21	89	820	61	499	3,495
157	53	479	3,933	N/A	N/A	N/A	65	101	1,700
158	66	132	2,189	57	112	1,380	73	277	3,114
159	71	96	2,178	45	16	496	71	522	4,437
160	68	564	3,537	N/A	N/A	N/A	67	570	5,219
161	65	645	3,868	61	152	1,971	58	30	919
162	N/A	N/A	N/A	52	66	1,160	67	469	5,496
163	66	213	2,911	59	12	613	69	670	5,745
164	67	553	4,620	58	158	2,082	68	324	3,345
165	57	261	3,101	63	28	821	58	63	1,096
166	18	5	116	63	301	3,379	N/A	N/A	N/A
167	N/A	N/A	N/A	59	119	1,698	62	38	544
168	33	201	3,009	N/A	N/A	N/A	N/A	N/A	N/A
169	23	110	1,955	59	32	554	67	8	260
170	63	511	3,942	60	32	394	60	34	831
171	66	109	3,781	62	39	447	66	21	636
172	63	114	1,824	61	31	378	N/A	N/A	N/A
173	67	61	1,507	61	49	508	57	47	1,062
174	N/A	N/A	N/A	52	101	1,141	65	162	1,610
175	N/A	N/A	N/A	28	144	1,541	55	106	1,470
176	40	32	427	43	136	1,745	59	135	1,745
177	43	130	1,198	48	19	530	N/A	N/A	N/A
178	42	182	1,377	N/A	N/A	N/A	N/A	N/A	N/A

[a]indicates the number of calf re-locations used to estimate the 99% UD and CUA.

[b]CUA refers to the concentrated use area, which was the portion of the 99% fixed kernel utilization distribution with greater than mean observation density.

[c]99% UD refers to the 99% fixed kernel utilization distribution.

[d]N/A indicates that sample size was too small to estimate a utilization distribution.

Table 1.2. Daily selection models, daily utilization distribution scale, 1992. Porcupine Caribou Herd daily selection models contrasting concentrated use locations with peripheral locations. Parameter estimates were from logistic regression models. Concentrated use areas were regions with greater than mean observation density, and peripheral areas comprised the remainder of the daily 99% utilization distirbution.

		Parameter Estimates							
Julian Day	Intercept	NDVI [a]	NDVI rate [b]	Wet Sedge	HTT [c]	Elevation	LR test p-value [d]	c-value [e]	delta-AIC [f]
155	3.854	2.194	0.380	---[g]	-0.090	-0.048	0.104	0.823	-0.873
157	-2.367	-0.367	1.373	0.433	2.663	0.001	0.003	0.820	7.861
158	---	---	-2.380	0.516	0.340	0.004	0.001	0.836	18.665
159	---	2.227	---	0.806	0.374	0.003	0.001	0.851	19.521
160	1.445	0.577	-1.643	-1.019	0.611	-0.011	0.001	0.839	14.793
161	2.012	1.222	-2.219	-1.024	-1.967	-0.004	0.001	0.833	14.159
163	-1.262	0.473	-0.633	0.423	-0.876	0.006	0.200	0.684	-2.715
164	-0.993	2.502	-0.143	0.864	-0.372	-0.005	0.026	0.742	2.697
165	-0.237	2.421	-0.426	0.307	-1.200	-0.008	0.023	0.740	3.017
166	---	---	---	---	---	-0.062	0.008	0.950	5.514
168	-0.414	2.199	-2.799	---	-1.490	-0.001	0.006	0.901	6.512
169	0.267	-0.995	-1.322	---	-0.935	0.005	0.406	0.750	-4.921
170	0.188	2.779	1.145	---	-0.517	-0.013	0.001	0.812	13.155
171	-0.560	1.336	0.613	2.252	-0.345	-0.012	0.107	0.699	-0.934
172	-0.184	2.096	0.373	---	0.262	-0.013	0.002	0.805	8.814
173	-2.666	1.869	0.477	---	0.373	0.003	0.014	0.735	4.242
176	-2.343	-0.259	0.412	0.203	0.755	0.017	0.650	0.638	-6.677
177	---	-1.380	2.582	0.193	-0.850	0.095	0.001	0.866	12.734
178	-5.841	0.129	0.813	0.544	0.159	0.029	0.033	0.823	2.156

Table 1.2, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC is the $AIC_{null\ model}$ - $AIC_{full\ model}$.

[g]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.3. Daily selection models, daily utilization distribution scale, 1993. Porcupine Caribou Herd daily selection models contrasting concentrated use locations with peripheral locations. Parameter estimates were from logistic regression models. Concentrated use areas were regions with greater than mean observation density, and peripheral areas comprised the remainder of the daily 99% utilization distribution.

		Parameter Estimates							
Julian Day	Intercept	NDVI [a]	NDVI rate [b]	Wet Sedge	HTT [c]	Elevation	LR test p-value [d]	c-value [e]	delta-AIC [f]
155	2.067	-0.590	-0.649	---[g]	0.628	-0.015	0.002	0.786	9.515
156	---	---	---	---	0.632	0.017	0.014	0.918	4.236
158	5.696	-1.641	-2.875	---	-1.231	-0.018	0.001	0.895	22.400
159	3.307	0.298	-0.889	---	-1.019	-0.015	0.025	0.782	2.852
161	0.845	-0.319	-1.058	---	0.111	-0.002	0.186	0.669	-2.498
162	-1.870	1.228	0.388	---	-0.414	0.004	0.007	0.790	5.951
163	---	---	-1.275	---	-0.968	0.002	0.001	0.892	16.371
164	-1.314	-0.815	-0.629	---	-0.273	0.007	0.006	0.732	6.390
165	-1.049	-0.800	-0.071	---	-0.824	0.005	0.190	0.711	-2.553
166	1.895	0.205	0.203	---	-1.332	-0.018	0.001	0.858	15.930
167	1.257	-0.873	1.881	---	0.055	-0.028	0.001	0.863	17.647
169	---	-1.851	1.211	---	-0.393	0.034	0.001	0.834	11.296
170	-3.321	-0.624	0.589	---	0.022	0.014	0.263	0.690	-3.528
171	-1.831	-0.952	-2.186	---	-0.530	0.013	0.006	0.785	6.536
172	---	-0.381	1.532	---	0.083	0.020	0.002	0.811	8.502
173	1.047	1.488	-1.471	-0.102	0.428	-0.004	0.126	0.674	-1.388
174	-4.088	0.007	-1.345	---	1.359	0.017	0.001	0.851	17.545
175	---	0.688	---	1.643	0.843	-0.030	0.003	0.877	8.430
176	---	-1.202	-1.195	---	2.418	0.024	0.001	0.926	22.831
177	-2.822	0.132	0.132	---	-1.203	0.010	0.004	0.843	7.171

Table 1.3, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC is the $AIC_{null\ model} - AIC_{full\ model}$.

[g]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.4. Daily selection models, daily utilization distribution scale, 1994. Porcupine Caribou Herd daily selection models contrasting concentrated use locations with peripheral locations. Parameter estimates were from logistic regression models. Concentrated use areas were regions with greater than mean observation density, and peripheral areas comprised the remainder of the daily 99% utilization distribution.

		Parameter Estimates							
Julian Day	Intecept	NDVI [a]	NDVI rate [b]	Wet Sedge	HTT [c]	Elevation	LR test p-value [d]	c-value [e]	delta-AIC [f]
155	0.813	1.211	0.536	-0.463	0.811	-0.016	0.008	0.754	5.696
156	3.214	1.450	-1.833	1.055	0.528	-0.023	0.001	0.857	17.383
157	-0.575	1.025	0.752	1.754	1.423	-0.011	0.008	0.767	5.725
158	-0.209	0.851	0.789	-0.114	0.398	-0.010	0.049	0.754	1.114
159	0.355	0.801	-0.699	0.159	0.273	-0.010	0.307	0.677	-4.012
160	0.192	2.412	0.415	0.360	0.976	-0.017	0.001	0.814	13.641
161	-0.022	-1.047	-0.147	0.923	0.549	-0.003	0.186	0.713	-2.501
162	1.585	-0.173	-1.474	0.290	-0.069	-0.008	0.016	0.774	4.021
163	1.017	0.434	-0.235	1.725	0.580	-0.009	0.013	0.688	4.550
164	1.120	2.320	-0.028	-1.068	-1.053	-0.017	0.001	0.796	9.992
165	-1.242	-0.506	1.503	---[g]	-0.444	0.000	0.155	0.671	-1.970
167	0.208	0.547	-0.151	---	-1.060	-0.003	0.525	0.646	-5.831
169	0.126	-1.579	-1.120	---	---	0.000	0.010	0.823	5.127
170	-2.426	---	-1.529	0.000	---	0.007	0.001	0.872	15.635
171	-1.747	-0.945	-0.607	---	---	0.002	0.213	0.743	-2.889
173	-1.769	2.648	0.989	0.000	-1.685	-0.001	0.003	0.803	7.756
174	-0.108	0.298	0.833	---	-0.435	-0.003	0.219	0.663	-2.977
175	-1.121	0.798	1.469	---	-1.226	0.000	0.024	0.772	2.904
176	-14.676	---	2.121	---	-0.672	0.003	0.040	0.868	1.626

Table 1.4, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC is the $AIC_{null\ model} - AIC_{full\ model}$.

[g]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.5. Daily selection models, aggregate utilization distribution scale, 1992. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the aggregate utilization distribution (AUD). The AUD was estimated by merging all daily 99% fixed kernel utilization distributions from the 21-day study period.

		Parameter Estimates							
Julian Day	Intercept	NDVI[a]	NDVI rate[b]	Wet Sedge	HTT[c]	Elevation	LR test p-value[d]	c-value[e]	delta-AIC[f]
155	-2.195	2.440	-0.194	-1.164	-0.274	-0.006	0.001	0.792	13.630
157	-1.206	0.277	2.116	-1.301	0.724	-0.004	0.001	0.758	24.592
158	-1.466	1.969	1.416	-0.083	0.648	-0.006	0.001	0.746	22.780
159	-1.517	0.935	0.908	0.400	1.609	-0.003	0.001	0.743	23.385
160	-1.156	0.962	1.310	-0.247	1.004	-0.005	0.001	0.72	14.691
161	-0.749	0.866	-0.022	-0.033	0.848	-0.003	0.003	0.668	8.007
163	-0.388	0.791	-0.371	0.652	0.305	-0.003	0.025	0.649	2.827
164	-0.544	0.718	0.086	-0.030	0.359	-0.002	0.164	0.615	-2.129
165	-0.107	0.504	-1.029	0.371	0.828	-0.004	0.001	0.72	15.112
166	-1.131	1.106	-0.015	-0.516	0.426	-0.010	0.043	0.696	1.477
168	-2.168	1.005	0.185	0.591	0.184	0.001	0.138	0.656	-1.643
169	-0.998	0.007	-0.818	-1.722	-0.205	0.001	0.261	0.656	-3.501
170	-0.811	0.962	-0.130	-0.449	0.166	-0.001	0.054	0.662	0.873
171	-0.680	1.539	0.046	-0.410	0.251	-0.005	0.001	0.708	12.948
172	-0.309	1.716	-0.566	-0.690	0.325	-0.007	0.001	0.765	25.438
173	0.330	1.320	-0.199	-1.291	0.176	-0.009	0.001	0.759	26.053
176	-0.133	-2.158	-0.679	0.598	1.459	-0.004	0.001	0.79	26.028
177	0.032	-0.396	-0.445	-0.348	0.797	-0.004	0.053	0.643	0.913
178	-2.398	0.360	-0.095	2.266	2.315	-0.001	0.001	0.751	20.190

Table 1.5, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC was the $AIC_{null\ model} - AIC_{full\ model}$.

Table 1.6. Daily selection models, aggregate utilization distribution scale, 1993. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the aggregate utilization distribution (AUD). The AUD was estimated by merging all daily 99% fixed kernel utilization distributions from the 21-day study period.

	Parameter Estimates						LR test p		
Julian Day	Intercept	NDVI[a]	NDVI rate[b]	Wet Sedge	HTT[c]	Elevation	value[d]	c-value[e]	delta-AIC[f]
155	0.337	-0.068	-0.610	-1.207	0.718	-0.004	0.001	0.692	35.431
156	-1.902	1.046	-0.984	0.315	1.256	-0.004	0.004	0.760	25.998
158	0.507	-0.632	-1.302	-1.001	0.976	-0.004	0.001	0.756	48.093
159	-0.201	0.298	-1.612	-0.596	0.865	-0.004	0.001	0.740	41.625
161	-0.580	0.510	-0.739	0.204	0.046	0.000	0.224	0.628	24.266
162	-0.928	0.317	-1.446	0.713	1.056	0.000	0.005	0.661	10.857
163	-0.796	1.032	-1.144	-1.464	-0.563	0.000	0.001	0.703	31.654
164	-0.803	1.896	-1.573	0.957	0.019	-0.001	0.001	0.763	35.784
165	-0.269	0.061	-0.784	-0.972	0.195	0.000	0.212	0.597	24.256
166	0.653	0.661	0.617	-1.524	-0.270	-0.009	0.001	0.746	51.298
167	1.025	0.051	0.490	-1.907	0.025	-0.012	0.001	0.793	80.089
169	-2.347	1.084	1.604	-0.831	1.177	-0.003	0.001	0.789	89.546
170	-3.091	1.816	1.670	-0.307	0.965	-0.002	0.001	0.787	76.564
171	-0.623	0.637	0.242	-1.189	-0.440	-0.001	0.249	0.619	53.705
172	-5.112	1.236	3.830	---[g]	0.187	0.003	0.001	0.889	97.115
173	-2.385	2.757	1.229	0.788	-1.011	-0.001	0.001	0.797	70.373
174	-0.870	1.710	0.505	---	-0.416	-0.004	0.001	0.733	88.043
175	-3.456	-0.114	2.412	-0.680	-0.657	0.004	0.004	0.759	23.359
176	-2.246	-0.157	0.190	-0.553	0.709	0.004	0.057	0.681	47.814
177	-1.373	0.877	-0.280	-0.393	0.256	0.001	0.048	0.674	61.291

Table 1.6, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC was the $AIC_{null\ model} - AIC_{full\ model}$

[g]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.7. Daily selection models, aggregate utilization distribution scale, 1994. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the aggregate utilization distribution (AUD). The AUD was estimated by merging all daily 99% fixed kernel utilization distributions from the 21-day study period.

Julian Day	Parameter Estimates						LR test p-value[d]	c-value[e]	delta-AIC[f]
	Intercept	NDVI[a]	NDVI rate[b]	Wet Sedge	HTT[c]	Eleavtion			
155	-0.654	1.530	0.006	0.013	0.415	-0.004	0.001	0.684	12.379
156	-0.867	1.605	0.663	-0.170	-0.066	-0.004	0.001	0.730	12.164
157	-0.337	1.412	0.396	0.377	0.384	-0.006	0.001	0.688	15.679
158	-0.151	0.801	0.296	0.221	0.145	-0.004	0.005	0.634	6.949
159	0.020	0.487	0.375	0.022	0.458	-0.005	0.001	0.683	13.466
160	-0.255	0.462	0.568	-0.783	0.250	-0.004	0.003	0.666	7.752
161	-0.861	0.588	0.885	-0.445	0.000	-0.002	0.105	0.665	4.182
162	-0.650	0.420	0.693	-0.488	-0.146	-0.001	0.091	0.621	-0.519
163	0.565	0.228	-0.323	-1.391	0.046	-0.003	0.004	0.682	7.620
164	-0.210	0.413	0.422	-0.943	-0.052	-0.003	0.039	0.628	1.719
165	-1.071	0.819	1.415	0.041	0.787	-0.007	0.001	0.798	32.944
167	-2.314	2.987	-0.222	-1.555	-0.038	-0.001	0.001	0.767	42.444
169	-1.236	1.500	-0.993	-0.910	-0.227	0.001	0.001	0.770	32.276
170	-1.415	2.408	-0.864	---[g]	-2.717	0.001	0.001	0.850	58.319
171	-3.216	2.624	0.450	0.613	-1.192	0.002	0.001	0.809	40.548
173	-0.475	0.939	-1.153	---	-0.785	0.000	0.001	0.761	26.389
174	-1.297	1.755	0.290	-0.858	0.569	-0.003	0.001	0.747	23.007
175	-1.144	1.780	0.154	-0.059	1.423	-0.008	0.001	0.792	30.880
176	-0.726	1.189	-0.019	-1.248	0.535	-0.004	0.001	0.730	15.262

Table 1.7, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass. (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The likelihood ratio tested the null hypothesis that the model had zero slope.

[e] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[f]delta-AIC was the $AIC_{null\ model} - AIC_{full\ model}$

[g]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.8. Daily selection models, historical extent of calving scale, 1992. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the historical extent of calving, 1983-2001[a], clipped to the extent of the landcover class map[b]. The historical extent of calving, 1983-2001 is the merged extent of all annual calving grounds from that 19-year period.

	Parameter Estimates								
Julian Day	Intercept	NDVI[c]	NDVI rate[d]	Wet Sedge	HTT[e]	Elevation	LR test p-value[f]	c-value[g]	delta-AIC[h]
155	-1.094	1.898	---[i]	-0.925	0.213	-0.008	0.001	0.911	44.727
157	-0.460	-0.181	0.297	-0.177	1.357	-0.004	0.001	0.742	25.027
158	0.324	-0.070	-0.295	0.643	1.815	-0.006	0.001	0.808	54.618
159	-1.010	0.482	0.331	0.981	1.435	-0.003	0.001	0.77	41.542
160	-0.101	0.358	-0.553	0.053	1.614	-0.004	0.001	0.814	54.000
161	-0.270	0.452	-0.587	0.578	1.187	-0.004	0.001	0.775	41.378
163	-1.440	1.567	0.930	1.706	0.313	-0.002	0.001	0.777	39.808
164	-0.014	0.518	-1.268	0.972	1.142	-0.003	0.001	0.808	51.088
165	-0.805	0.866	-0.434	0.679	1.265	-0.004	0.001	0.771	36.412
166	-0.844	1.090	-2.954	0.833	0.548	-0.007	0.001	0.902	27.311
168	-1.504	1.334	-0.984	0.574	0.356	-0.001	0.001	0.748	10.675
169	-0.419	0.965	-2.337	-1.465	-0.429	-0.003	0.001	0.823	19.968
170	-0.125	0.755	-0.986	0.754	0.464	-0.004	0.001	0.79	39.617
171	0.422	1.253	-0.441	-0.857	-0.407	-0.007	0.001	0.827	53.776
172	0.082	1.005	-1.774	-0.890	0.825	-0.007	0.001	0.861	68.618
173	0.650	0.465	-2.482	0.100	0.683	-0.008	0.001	0.83	76.040
176	0.157	-1.850	-2.498	1.523	1.804	-0.006	0.001	0.906	70.080
177	-0.118	-0.647	-0.352	0.110	1.248	-0.005	0.001	0.757	29.051
178	-1.911	0.499	-1.614	2.372	1.990	-0.003	0.001	0.836	47.281

Table 1.8, continued.

[a]Griffith et al. 2002.

[b]Jorgensen et al. 1994.

[c]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[d]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[e] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[f] The likelihood ratio tested the null hypothesis that the model had zero slope.

[g] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[h]delta-AIC was the $AIC_{null\ model} - AIC_{full\ model}$.

[i]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.9. Daily selection models within the historical extent of calving scale, 1993. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the historical extent of calving, 1983-2001[a], clipped to the extent of the landcover class map[b]. The historical extent of calving, 1983-2001 is the merged extent of all annual calving grounds from that 19-year period.

	Parameter Estimates						LR test		
Julian Day	Intercept	NDVI[c]	NDVI rate[d]	Wet Sedge	HTT[e]	Elevation	p-value[f]	c-value[g]	delta-AIC[h]
155	0.496	0.079	-0.665	-0.694	1.012	-0.005	0.001	0.774	35.431
156	-1.707	0.613	-0.668	0.804	2.361	-0.005	0.001	0.868	25.998
158	0.559	-0.444	-1.280	-1.400	1.485	-0.004	0.001	0.825	48.093
159	-0.384	0.295	-1.688	0.111	1.836	-0.004	0.001	0.825	41.625
161	0.108	0.742	-0.813	0.565	0.371	-0.004	0.001	0.746	24.266
162	-0.201	0.611	-1.037	0.500	0.311	-0.002	0.001	0.705	10.857
163	0.398	0.884	-1.393	-2.215	0.050	-0.003	0.001	0.776	31.654
164	0.392	0.817	-1.485	-0.466	0.424	-0.004	0.001	0.792	35.784
165	0.725	-0.002	-1.309	-1.833	0.312	-0.003	0.001	0.761	24.256
166	0.952	-0.847	-0.112	-0.933	0.568	-0.007	0.001	0.795	51.298
167	---[i]	-0.612	---	-1.614	1.205	-0.010	0.001	0.873	80.089
169	---	-0.311	---	-0.820	2.538	-0.006	0.001	0.909	89.546
170	---	-0.289	---	-1.889	1.569	-0.004	0.001	0.878	76.564
171	---	0.084	---	-2.090	0.491	-0.002	0.001	0.787	53.705
172	---	1.787	---	---	1.295	-0.004	0.001	0.898	97.115
173	---	1.732	---	-0.751	0.630	-0.003	0.001	0.857	70.373
174	---	2.582	---	---	-0.011	-0.007	0.001	0.908	88.043
175	---	0.723	---	-0.702	0.367	-0.003	0.001	0.787	23.359
176	---	0.533	---	-1.192	0.883	-0.002	0.001	0.835	47.814
177	---	2.044	---	-0.075	0.491	-0.002	0.001	0.861	61.291

Table 1.9, continued.

[a]Griffith et al. 2002.

[b]Jorgensen et al. 1994.

[c]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[d]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[e] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[f] The likelihood ratio tested the null hypothesis that the model had zero slope.

[g] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[h]delta-AIC was the $AIC_{null\ model} - AIC_{full\ model}$.

[i]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.10. Daily selection models, historical extent of calving scale, 1994. Parameter estimates are from logistic regression models contrasting radio-collared calf locations from the Porcupine Caribou Herd with random locations within the historical extent of calving[a], 1983-2001, clipped to the extent of the landcover class map[b]. The historical extent of calving, 1983-2004 is the merged extent of all annual calving grounds from that 19-year period.

	Parameter Estimates								
Julian Day	Intercept	NDVI[c]	NDVI rate[d]	Wet Sedge	HTT[e]	Elevation	LR test p value[f]	c-value[g]	delta-AIC[h]
155	-1.122	0.716	1.425	-0.594	1.140	-0.004	0.001	0.776	34.825
156	-1.223	0.840	1.151	-0.365	0.750	-0.003	0.001	0.722	21.962
157	-1.137	1.308	1.500	0.326	0.673	-0.004	0.001	0.768	39.708
158	-0.802	0.726	1.329	-0.042	0.388	-0.004	0.001	0.731	30.847
159	-0.321	0.321	1.012	-0.836	0.399	-0.004	0.001	0.773	40.678
160	-0.687	0.541	1.338	-0.686	0.822	-0.004	0.001	0.797	47.042
161	0.038	-0.846	0.002	-0.889	0.924	-0.003	0.001	0.700	12.808
162	-0.100	-0.183	0.314	0.311	0.676	-0.003	0.001	0.731	23.984
163	-0.210	0.437	0.610	-0.753	0.251	-0.003	0.001	0.733	26.096
164	-0.018	-0.432	1.095	-1.487	0.146	-0.005	0.001	0.784	38.706
165	-1.116	-0.157	1.655	0.398	1.027	-0.006	0.001	0.836	55.910
167	-1.725	1.024	1.067	-0.900	0.799	-0.001	0.001	0.769	29.266
169	-1.015	0.987	0.468	-1.146	0.687	-0.001	0.001	0.696	12.728
170	-0.446	0.603	0.189	---[i]	-1.114	-0.001	0.008	0.629	5.683
171	-0.812	1.077	0.044	0.124	-0.919	0.000	0.017	0.646	3.798
173	-0.292	1.016	-0.219	---	-0.141	-0.002	0.001	0.702	15.246
174	-1.261	0.704	1.532	-0.764	0.784	-0.004	0.001	0.802	47.351
175	-2.314	0.924	2.066	1.018	1.650	-0.006	0.001	0.879	71.582
176	-0.629	-0.422	0.237	-1.122	2.025	-0.004	0.001	0.817	51.722

Table 1.10, continued.

[a]Griffith et al. 2002.

[b]Jorgensen et al. 1994.

[c]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[d]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[e] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[f] The likelihood ratio tested the null hypothesis that the model had zero slope.

[g] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

[h]delta-AIC was the $AIC_{null\ model}$ - $AIC_{full\ model}$.

[i]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.11. Daily selection model coefficients of variation, 1992. Parameter estimate coefficients of variation (CV's) from daily logistic regression habitat selection models for radio-collared calves of the Porcupine Caribou Herd, in Alaska. 18 to 67 radio-collared calves were relocated daily during the study period.

	Habitat Variables									
	NDVI[a]		NDVI rate[b]		Elevation		Wet Sedge		Herb Tuss. Tundra	
	Analysis Scale									
Julian Day	AUD[c]	HE[d]	AUD	HE	AUD	HE	AUD	HE	AUD	HE
155	0.377	0.473	5.007	---[e]	0.636	0.461	0.731	0.987	2.102	2.964
157	1.851	2.341	0.234	1.345	0.469	0.317	0.459	3.277	0.624	0.320
158	0.249	11.888	0.332	2.315	0.300	0.269	5.996	0.774	0.620	0.237
159	0.488	0.834	0.472	1.132	0.570	0.337	1.192	0.522	0.252	0.269
160	0.450	1.150	0.318	0.693	0.370	0.281	2.315	11.351	0.374	0.256
161	0.463	0.942	17.310	0.639	0.555	0.311	15.104	0.961	0.450	0.344
163	0.587	0.285	0.930	0.712	0.486	0.483	0.758	0.298	1.309	1.282
164	0.573	0.752	3.851	0.294	0.606	0.311	16.147	0.602	1.070	0.368
165	0.925	0.517	0.372	0.906	0.432	0.323	1.585	0.882	0.517	0.330
166	0.614	0.649	40.512	0.371	0.438	0.508	1.730	1.260	1.546	1.214
168	0.531	0.399	2.460	0.450	1.219	0.863	1.194	1.356	2.555	1.395
169	89.134	0.632	0.670	0.283	2.498	0.390	0.638	0.796	2.743	1.448
170	0.433	0.581	2.641	0.534	1.068	0.269	1.436	1.060	2.234	0.876
171	0.288	0.352	7.667	1.169	0.362	0.212	1.738	0.876	1.495	0.944
172	0.254	0.459	0.652	0.353	0.341	0.247	0.863	0.685	1.263	0.510
173	0.326	0.903	1.865	0.325	0.288	0.253	0.446	7.069	2.299	0.604
174	1.209	2.011	0.529	0.621	0.454	0.591	0.923	0.564	1.021	0.518
176	0.303	0.351	0.643	0.335	0.749	0.390	0.917	0.431	0.377	0.328
177	1.209	0.704	0.865	1.168	0.579	0.329	1.666	21.368	0.552	0.396
178	1.501	1.125	4.574	0.500	1.800	0.673	0.305	0.311	0.246	0.294

Table 1.11, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimates the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's during the 21-day study period.

[d]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

[e]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.12. Daily selection model coefficients of variation, 1993. Parameter estimate coefficients of variation (CV's) from daily logistic regression habitat selection models for radio-collared calves of the Porcupine Caribou Herd, in Alaska. 21 to 67 radio-collared calves were relocated daily during the study period.

	Habitat Variables									
	NDIV[a]		NDVI rate[b]		Elevation		Wet Sedge		Herb. Tuss. Tundra	
	Analysis Scale									
Julian Day	AUD[c]	HE[d]	AUD	HE	AUD	HE	AUD	HE	AUD	HE
155	7.007	5.268	0.814	0.587	0.431	0.246	0.570	1.056	0.527	0.381
156	0.825	1.067	1.037	1.026	0.728	0.420	3.953	1.556	0.489	0.259
158	0.795	1.123	0.445	0.360	0.412	0.271	1.208	0.814	0.407	0.280
159	1.730	1.499	0.373	0.300	0.464	0.335	1.481	8.451	0.477	0.240
161	0.819	0.556	0.655	0.501	2.638	0.251	3.804	1.411	8.006	1.019
162	1.493	0.666	0.397	0.410	3.922	0.364	1.002	1.432	0.394	1.307
163	0.454	0.455	0.524	0.321	3.847	0.257	0.781	0.494	0.733	8.435
164	0.226	0.488	0.366	0.279	0.802	0.240	0.887	1.587	21.297	0.921
165	7.337	---[e]	0.526	0.289	3.190	0.302	0.848	0.454	1.906	1.237
166	0.751	0.580	0.601	3.587	0.279	0.229	0.479	0.842	1.551	0.748
167	9.837	1.016	0.808	---	0.254	0.261	0.379	0.454	17.706	0.455
169	0.457	1.761	0.329	---	0.676	0.341	1.374	1.497	0.345	0.192
170	0.259	1.514	0.304	---	1.033	0.403	4.150	0.612	0.427	0.280
171	0.636	4.606	1.549	---	1.905	0.593	0.947	0.528	0.798	0.812
172	0.435	0.262	0.201	---	0.630	0.369	---	---	2.309	0.355
173	0.246	0.255	0.351	---	1.343	0.417	1.242	1.169	0.465	0.662
174	0.322	0.229	0.852	---	0.513	0.281	---	---	0.934	43.639
175	5.130	0.746	0.305	---	0.574	0.445	1.789	1.625	0.836	1.458
176	3.362	0.957	2.261	---	0.433	0.510	2.098	0.987	0.606	0.573
177	0.574	0.242	1.354	---	2.573	0.638	2.157	12.033	1.630	0.899

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimates the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's during the 21-day study period.

[d]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

[e]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.13. Daily selection model coefficients of variation, 1994. Parameter estimate coefficients of variation (CV's) from daily logistic regression habitat selection models for radio-collared calves of the Porcupine Caribou Herd, in Alaska. 57 to 71 radio-collared calves were relocated daily during the study period.

	Habitat Variables									
	NDVI[a]		NDVI rate[b]		Elevation		Wet Sedge		Herb. Tuss. Tundra	
	Analysis Scale									
Julian Day	AUD[c]	HE[d]	AUD	HE	AUD	HE	AUD	HE	AUD	HE
155	0.297	0.757	66.116	0.352	0.379	0.321	39.830	0.898	0.941	0.353
156	0.291	0.581	0.534	0.372	0.350	0.368	3.652	1.652	6.043	0.502
157	0.335	0.431	0.872	0.317	0.308	0.295	1.364	1.592	1.016	0.597
158	0.478	0.703	1.106	0.342	0.337	0.293	2.492	13.514	2.437	0.917
159	0.892	1.549	0.920	0.427	0.315	0.264	26.129	0.646	0.848	0.902
160	0.885	0.979	0.615	0.324	0.379	0.272	0.766	0.945	1.491	0.502
161	0.796	0.553	0.405	---[e]	0.541	0.389	1.363	0.672	---	0.455
162	0.932	2.380	0.501	1.179	0.757	0.295	1.200	2.317	2.607	0.603
163	1.771	0.953	1.099	0.619	0.321	0.266	0.451	0.873	8.479	1.605
164	1.044	1.060	0.810	0.353	0.454	0.253	0.658	0.435	7.291	2.739
165	0.657	3.327	0.314	0.285	0.367	0.314	18.036	1.969	0.590	0.384
167	0.257	0.353	2.398	0.377	1.497	0.602	0.761	1.249	11.336	0.482
169	0.316	0.343	0.511	0.755	2.424	0.577	1.271	0.973	1.742	0.566
170	0.221	0.580	0.590	1.872	0.429	0.923	---	---	0.201	0.470
171	0.234	0.306	0.933	7.516	3.161	1.749	1.678	7.437	0.374	0.469
173	0.465	0.345	0.385	1.606	0.490	0.407	---	---	0.551	3.014
174	0.282	0.608	1.465	0.290	0.356	0.309	0.965	1.083	0.696	0.488
175	0.314	0.549	2.902	0.290	0.531	0.329	12.900	0.819	0.321	0.278
176	0.423	1.089	21.381	1.715	---	0.334	0.659	0.737	0.749	0.200

Table 1.13, continued.

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimates the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's during the 21-day study period.

[d]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

[e]--- indicates that quasi-complete separation resulted in an unreliable parameter estimate.

Table 1.14. Daily selection of habitat variables by scale and year, 1992-1994. The number of days each habitat variable had a positive parameter estimate in daily logistic regression habitat selection models, is listed below. Sample size ranged from 18 to 73 radio-collared calves, from the Porcupine Caribou Herd, in Alaska.

		Habitat Variables									
		NDVI[a]		NDVI rate[b]		Wet Sedge		HTT[c]		Elevation	
		Analysis Scale									
Year	Days[d]	AUD[e]	HE[f]	AUD	HE	AUD	HE	AUD	HE	AUD	HE
1992[f]	19	18	15	7	16	7	15	18	17	2	0
1993[g]	20	16	14	10	10	5	4	14	19	5	0
1994[h]	19	19	14	13	18	6	5	11	16	4	0

[a]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[b]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[c] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[d] The number of days in the study period with a sample size sufficient to estimate a 99% fixed kernel utilization distribution.

Table 1.14, continued.

[e]AUD was the aggregate utilization distribution, built by merging all daily 99% fixed kernel utilization distributions (UD's) from the 21-day study period.

[f]HE was the historical extent of calving, clipped to the extent of the landcover class map (Jorgensen et al. 1994). The historical extent of calving, 1983-2001,

was built by merging all of annual calving grounds during that 19-year period (Griffith et al. 2002).

Table 1.15. Linear regression tests for selection trend, 1992. The signifiance of linear relationships between each logistic regression daily habitat selection model parameter estimate and Julian day was tested. Parameter estimates biased by quasi-complete separation and parameter estimates from nonsignicant daily selection models were excluded from the analyses.

Scale	Habitat Variable	Intercept	Intercept SE	Slope	Slope SE	F-Test p-value	r^2	n
AUD [a]	NDVI[b]	11.193	6.155	-0.062	0.037	0.120	0.189	14
AUD	NDVI rate[c]	11.646	4.692	-0.069	0.028	0.031	0.332	14
AUD	Wet Sedge	-8.811	5.502	0.053	0.033	0.139	0.173	14
AUD	HTT[d]	-4.305	4.024	0.031	0.024	0.232	0.117	14
AUD	Elevation	-0.004	0.015	0.000	0.000	0.931	0.001	14
HE [e]	NDVI	7.004	4.606	-0.039	0.028	0.180	0.103	19
HE	NDVI rate	13.153	5.109	-0.085	0.031	0.013	0.327	18
HE	Wet Sedge	-3.121	5.717	0.021	0.034	0.544	0.022	19
HE	HTT	1.405	4.100	0.003	0.025	0.906	0.001	19
HE	Elevation	-0.002	0.012	0.000	0.000	0.816	0.003	19

[a]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's.

Table 1.15. Continued.

[b]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[c]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[d] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

Table 1.15, continued.

[e]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

Table 1.16. Linear regression tests for selection trend, 1993. The signifiance of linear relationships between logistic regression daily habitat selection model parameter estimates and Julian day was tested. Parameter estimates biased by quasi-complete separation and parameter estimates from insignicant daily selection models were excluded from the analyses.

Scale	Habitat Variable	Intercept	Intercept SE	Slope	Slope SE	F-Test p-value	r^2	n
AUD [a]	NDVI[b]	-5.577	5.120	0.038	0.031	0.231	0.094	16
AUD	NDVI rate[c]	-23.103	7.170	0.140	0.043	0.005*	0.414	16
AUD	Wet sedge	-1.825	5.561	0.008	0.033	0.817	0.004	14
AUD	HTT[d]	8.187	3.774	-0.047	0.023	0.054	0.225	16
AUD	Elevation	-0.038	0.020	0.000	0.000	0.091	0.176	16
HE [e]	NDVI	-9.347	4.767	0.059	0.029	0.052	0.194	19
HE	NDVI rate	-0.326	7.199	-0.004	0.045	0.923	0.001	9
HE	Wet sedge	6.027	5.400	-0.041	0.033	0.223	0.091	17
HE	HTT	6.298	4.052	-0.032	0.024	0.200	0.090	17
HE	Elevation	-0.013	0.011	0.000	0.000	0.447	0.032	19

[a]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's.

[b]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[c]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

Table 1.16, continued.

[d] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[e]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001(Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

* indicates significance at the Bonferroni-adjusted $\alpha < 0.01$.

Table 1.17. Linear regression tests for selection trend, 1994. The significance of linear relationships between logistic regression daily habitat selection model parameter estimates and Julian day was tested. Parameter estimates biased by quasi-complete separation and parameter estimates from insignificant daily selection models were excluded from the analyses.

Scale	Habitat Variable	Intercept	Intercept SE	Slope	Slope SE	F-Test p-value	r^2	n
AUD [a]	NDVI[b]	-5.183	4.546	0.039	0.027	0.171	0.121	16
AUD	NDVI rate[c]	5.857	3.615	-0.035	-0.035	0.131	0.145	16
AUD	Wet sedge	4.946	4.142	-0.033	0.025	0.216	0.115	14
AUD	HTT[d]	2.966	5.454	-0.018	0.033	0.594	0.019	16
AUD	Elevation	-0.022	0.015	0.000	0.000	0.206	0.112	16
HE [e]	NDVI	-0.071	3.539	0.003	0.021	0.882	0.001	19
HE	NDVI rate	5.272	3.885	-0.027	0.024	0.268	0.068	19
HE	Wet sedge	-0.578	4.257	0.001	0.026	0.974	0.000	16
HE	HTT	0.751	4.313	-0.001	0.026	0.972	0.000	19
HE	Elevation	-0.009	0.009	0.000	0.000	0.548	0.020	19

[a]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's.

[b]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Walker et al. 2003; Jia et al. 2003).

[c]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

Table 1.17, continued.

[d] Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[e]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

Table 1.18. Calving period selection models. Porcupine caribou calving period logistic regression habitat selection model parameter estimates (SE) contrasting radio-collared calf locations with random available points at each of two analysis scales. Bold type on individual parameter estimates indicates statistical significance.

Year	1992		1993		1994	
Scale	AUD[a]	HE[b]	AUD	HE	AUD	HE
NDVI[c]	**0.629**	**0.425**	**0.850**	**0.682**	**0.946**	**0.248**
	(0.097)	(0.100)	(0.096)	(0.095)	(0.094)	(0.096)
NDVI rate[d]	0.062	**-0.669**	**0.226**	**0.208**	0.066	**0.777**
	(0.085)	(0.098)	(0.085)	(0.094)	(0.077)	(0.083)
Wet Sedge	**-0.165**	**0.540**	**-0.442**	**-0.399**	**-0.456**	-0.144
	(0.122)	(0.128)	(0.177)	(0.174)	(0.133)	(0.134)
Moist Sedge	-0.095	**0.270**	**0.547**	**1.058**	-0.040	**0.497**
	(0.101)	(0.106)	(0.103)	(0.101)	(0.087)	(0.088)
HTT[e]	**0.479**	**0.948**	**0.560**	**1.334**	**0.179**	**0.840**
	(0.088)	(0.093)	(0.097)	(0.095)	(0.083)	(0.081)
STT[f]	-0.108	-0.360	**0.476**	**1.016**	**0.393**	**0.721**
	(0.202)	(0.188)	(0.128)	(0.126)	(0.111)	(0.106)
Alpine	-0.472	**-1.674**	**-1.264**	**-2.369**	-0.350	**-1.544**
	(0.267)	(0.251)	(0.311)	(0.296)	(0.193)	(0.170)
Riparian	**0.525**	**0.652**	**0.808**	**0.768**	**0.737**	**0.997**
	(0.171)	(0.173)	(0.192)	(0.184)	(0.169)	(0.165)
Elevation	**-0.003**	**-0.003**	**-0.001**	**-0.003**	**-0.002**	**-0.001**
	(0.0004)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
P-value[g]	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
c-value[h]	0.643	0.786	0.645	0.79	0.654	0.751

[a]AUD was the aggregate utilization distribution analysis scale where radio-collared calf locations were contrasted with random available locations within the merged extent of all daily UD's during the 21-day study period.

[b]HE was the historical extent of calving analysis scale where radio-collared calf locations were contrasted with random available locations within the historical extent of calving, 1983-2001 (Griffith et al. 2002), clipped to the extent of the landcover class map (Jorgensen et al. 1994).

Table 1.18, continued.

[c]NDVI was the Normalized Difference Vegetation Index, which estimated relative photosynthetic above ground plant biomass (Hope et al. 1993; Jia et al. 2003; Walker et al. 2003).

[d]NDVI rate was the daily rate of increase of NDVI, which estimated the accumulation of new, highly digestible photosynthetic above ground plant biomass (Griffith et al. 2002).

[e]Herbaceous tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[f]Shrub tussock tundra landcover class (Jorgensen et al. 1994; Griffith et al. 2002).

[g] The likelihood ratio tested the null hypothesis that the model had no slope.

[h] The c-value estimated the probability that predictions and outcomes were concordant (Agresti 2002).

CONCLUSIONS

We estimated 30 linear relationships between logistic regression parameter estimates from our daily selection models and Julian date. Approximately 97 percent of our linear regression tests for selection trend were non-significant, indicating no linear trends in selection through time. This supported the assumption that the pre-defined 3-week calving period (Russell et al. 2002) is a single temporal domain for caribou.

The lack of linear trends in selection allowed us to estimate habitat selection by radio-collared calves over the entire calving period. They selected locations within the historical extent of calving and the aggregate utilization distribution with high NDVI, high NDVI rate of increase, herbaceous tussock tundra, and riparian landcover classes. While we detected subtle differences in the habitat attributes selected in this study and those selected in Griffith et al.'s (2002) study, these differences may be attributed to methodological variation between the two studies. Both studies found that caribou selected areas with high quantity and high quality forage biomass during the calving period.

Daily habitat selection by caribou was variable during the calving period, so estimates of habitat selection on a single day during this period may not be representative of selection patterns throughout the full calving period. The variable nature of habitat selection we detected at the daily scale may have been an artifact of insufficient sample size, limited accuracy of our habitat variables, or the importance of other habitat variables not included in our forced model.

Managers' ability to accurately estimate calving-related habitat selection should not be compromised because calving site locations are typically obtained over a 3- to 5-day period. If the 3 years included in our study represented typical selection patterns, then our results indicate that managers may accurately estimate habitat selection at any point during the pre-defined 3-week calving period (Russell at al. 2002).

Appendix A

Aggregate Utilization Distributions

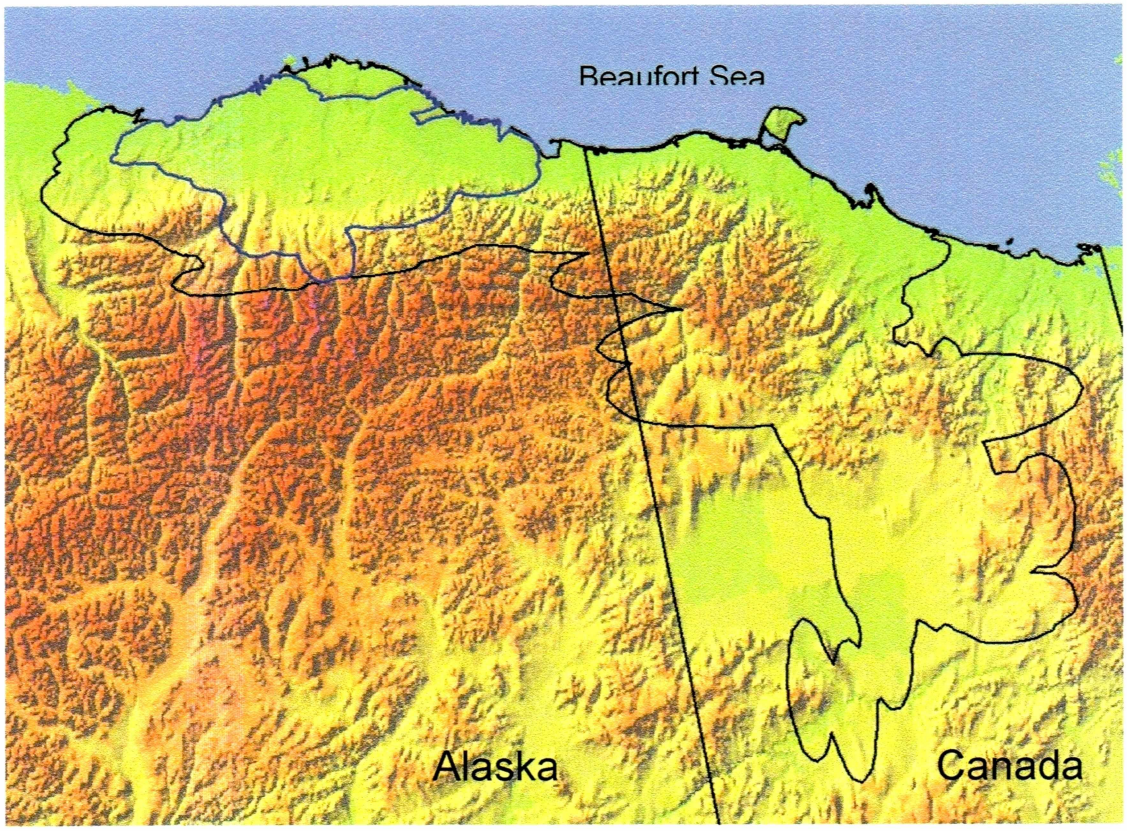


Figure A-1. Porcupine Caribou aggregate utilization distribution, 3 June-26 June, 1992. The area outlined in blue represents the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves. The black line shows the 1983-2001 historical extent of calving boundary.

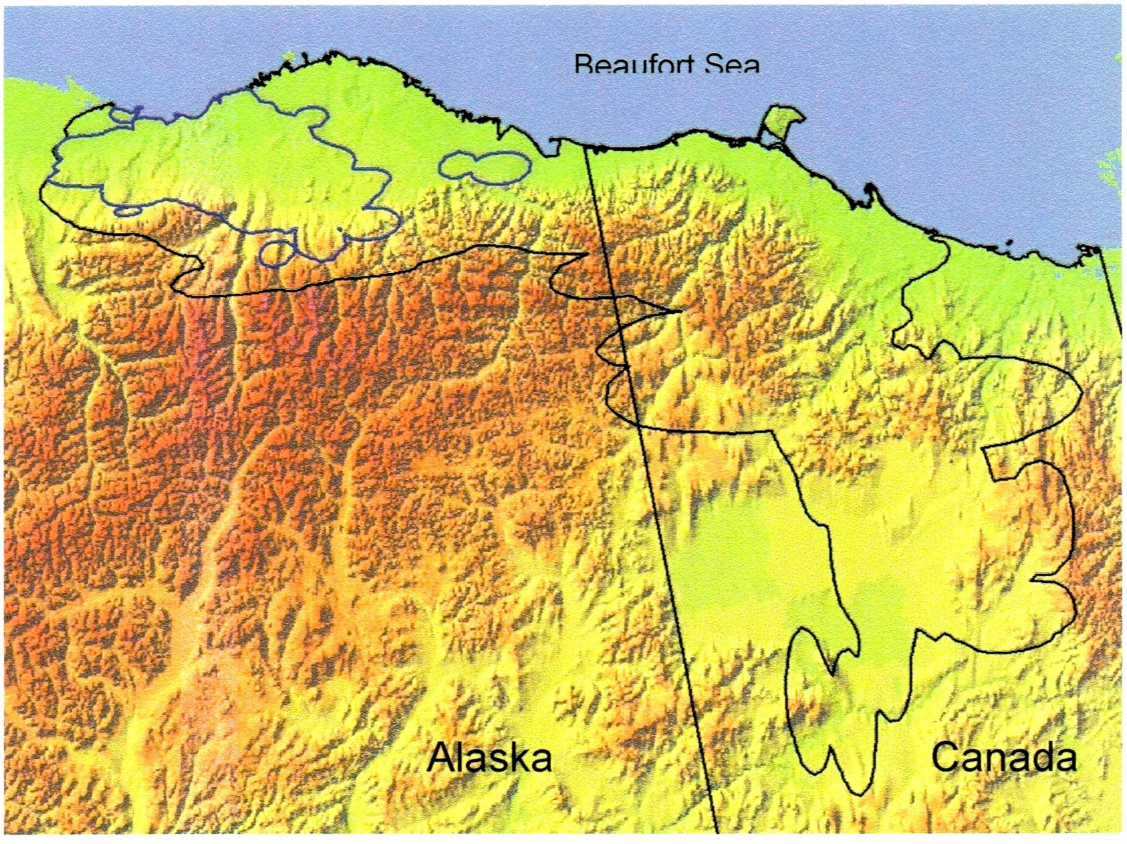


Figure A-2. Porcupine Caribou aggregate utilization distribution, 4 June-26 June, 1993. The area outlined in blue represents the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves. The black line shows the 1983-2001 historical extent of calving boundary.

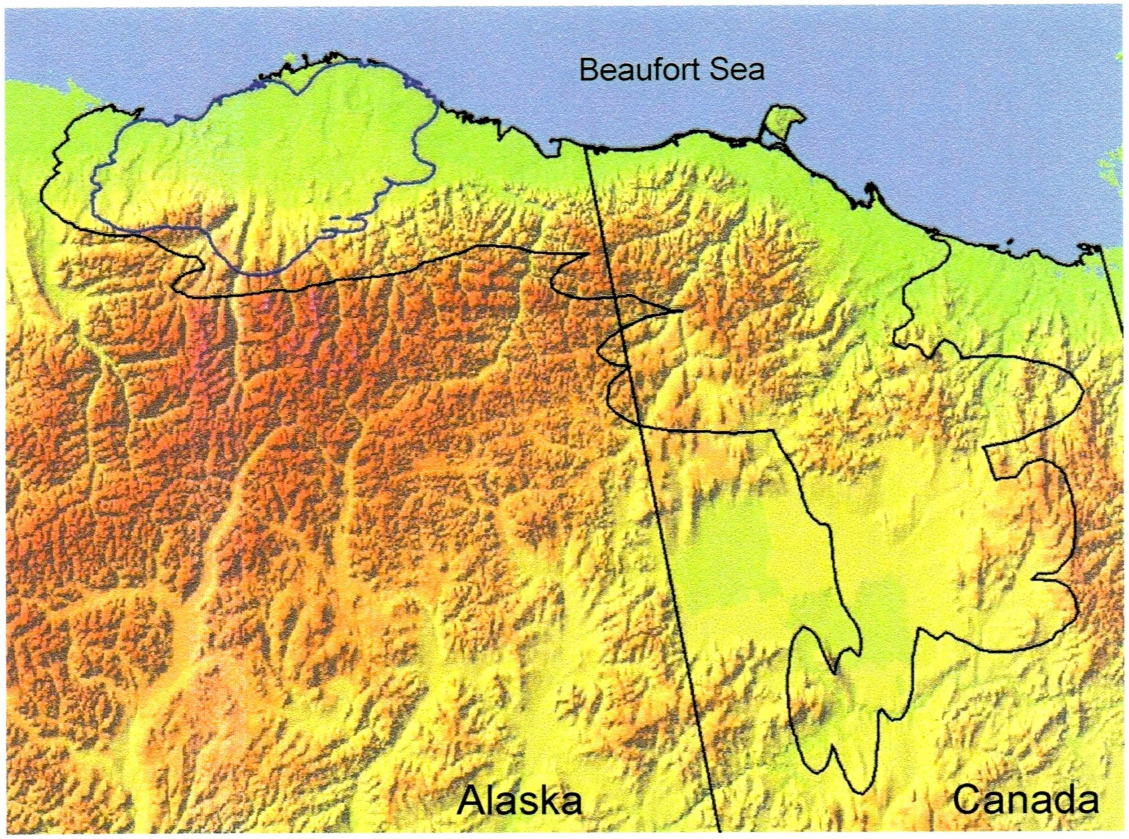


Figure A-3. Porcupine Caribou aggregate utilization distribution, 4 June-25 June, 1994. The area outlined in blue represents the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves. The black line shows the 1983-2001 historical extent of calving boundary.

Appendix B

Daily Utilization Distributions

Arctic National Wildlife Refuge
1002 Area
Historical Extent of Calving (1983-2001)
Alaska/Canada border
CUA
Daily UD

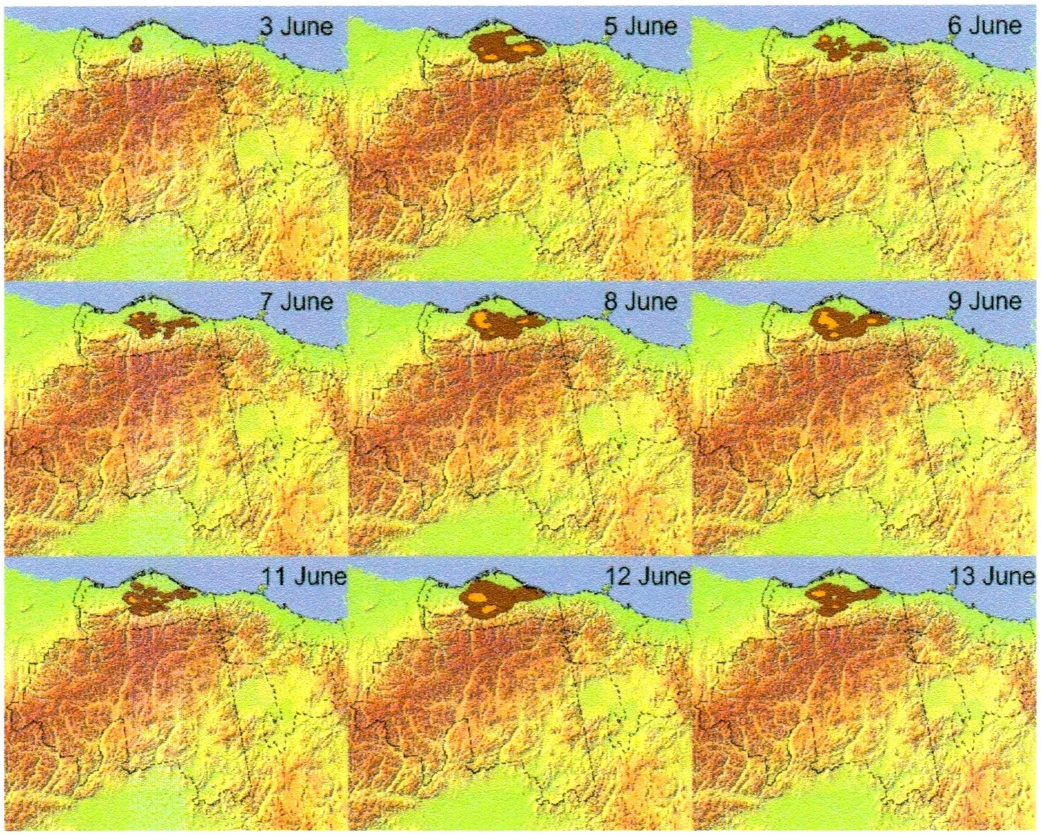


Figure B-1. 1992 Porcupine Caribou Herd (PCH) daily distributions. Brown areas correspond to the daily 99% fixed kernel utilization distribution (daily UD) of approximately 70 radio-collared calves, and the yellow areas represent concentrated use areas (CUA), where calf density was greater than average. Calves were captured within 48 hours of birth and outfitted with VHF radio collars. Weather permitting, calves were relocated daily with fixed wing aircraft.

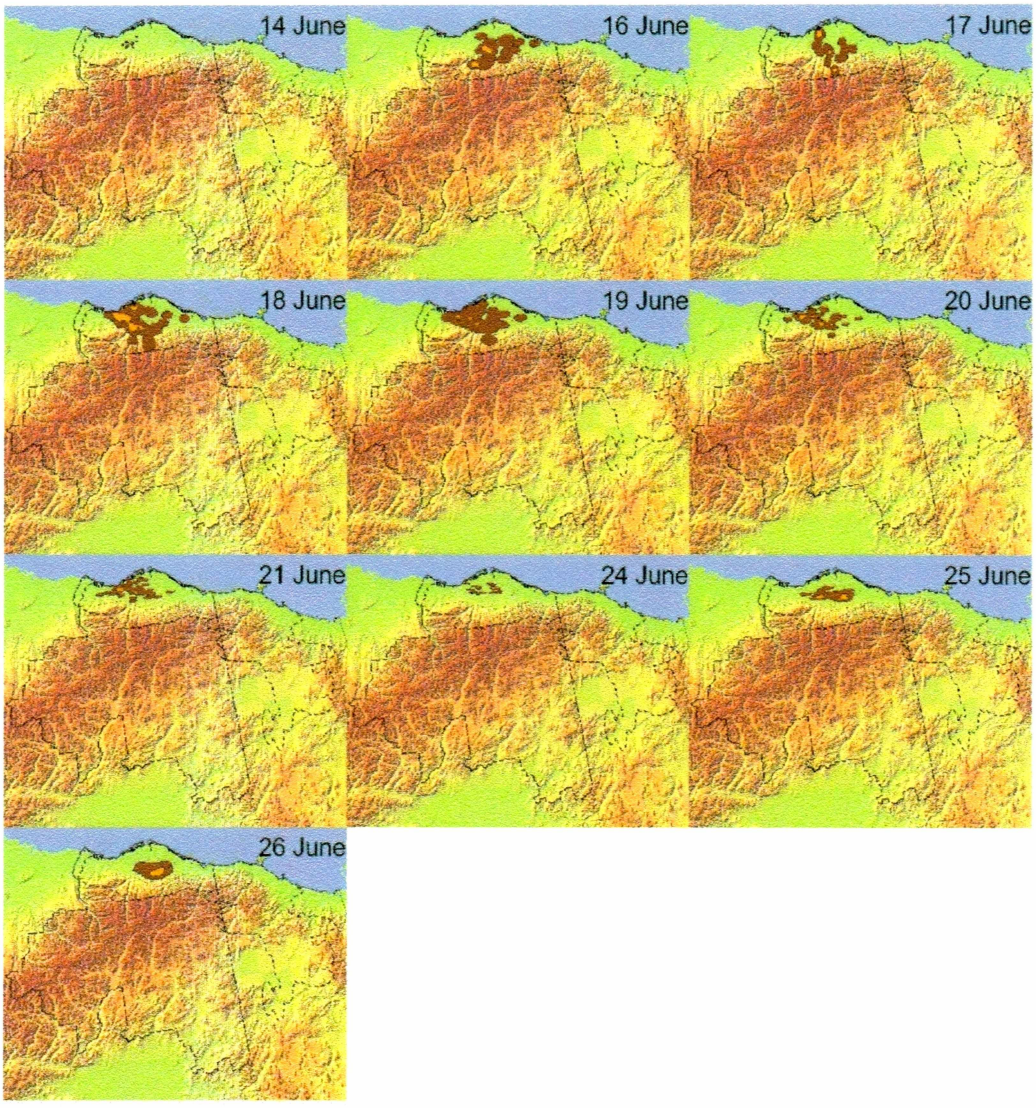


Figure B-1, continued.

Arctic National Wildlife Refuge
1002 Area
Historical Extent of Calving (1983-2001)
Alaska/Canada border
CUA
Daily UD

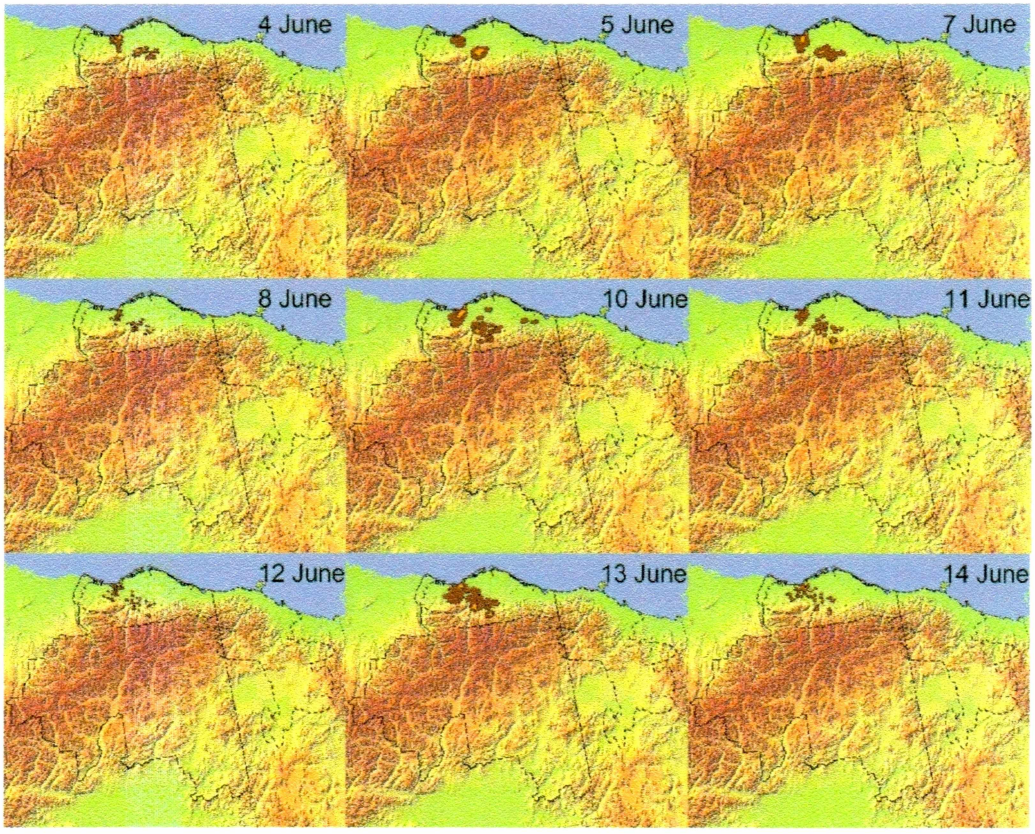


Figure B-2. 1993 Porcupine Caribou Herd (PCH) daily distributions. Brown areas correspond to the daily 99% fixed kernel utilization distribution (daily UD) of approximately 70 radio-collared calves, and the yellow areas represent concentrated use areas (CUA), where calf density was greater than average. Calves were captured within 48 hours of birth and outfitted with VHF radio collars. Weather permitting, calves were relocated daily with fixed wing aircraft.

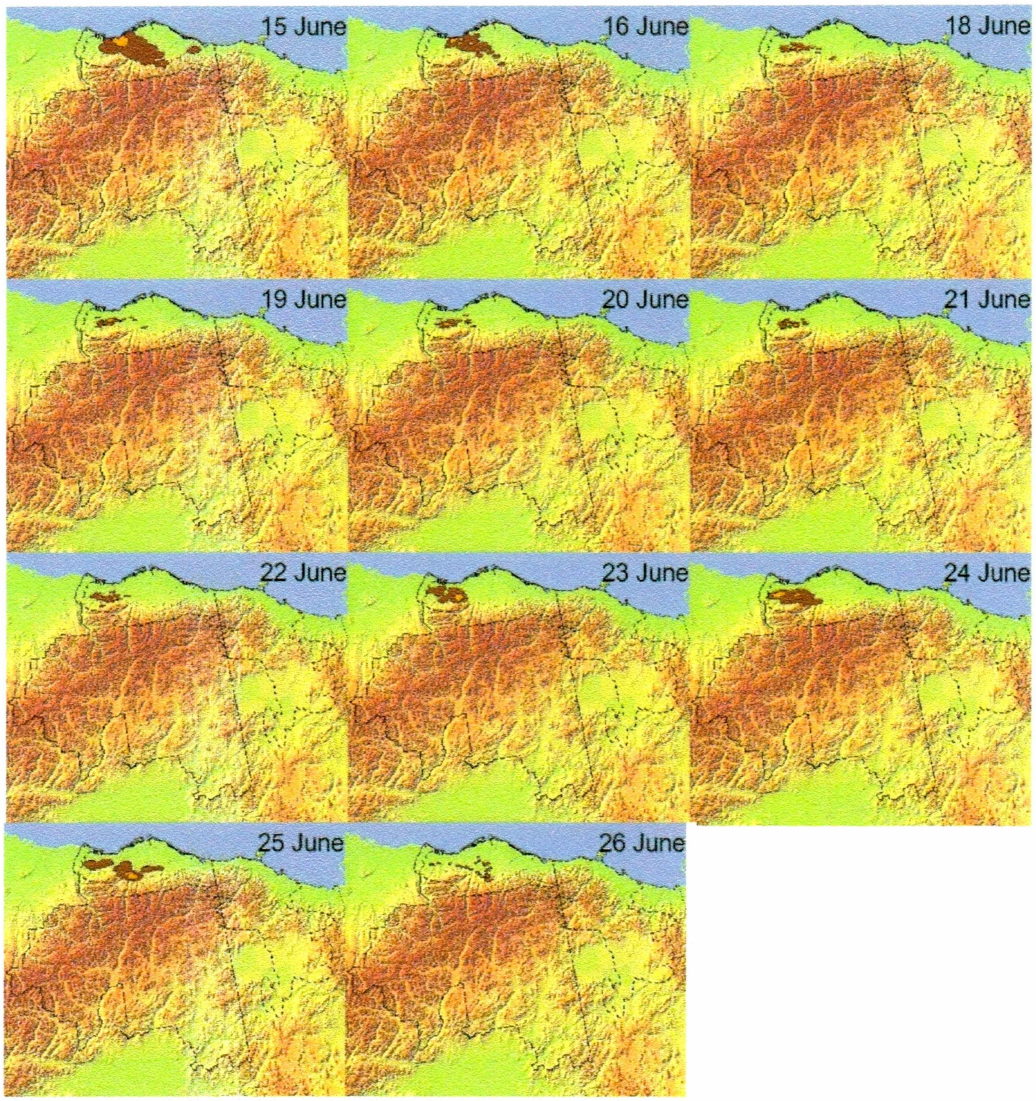
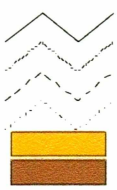


Figure B-2, continued.



Arctic National Wildlife Refuge
1002 Area
Historical Extent of Calving (1983-2001)
Alaska/Canada border
CUA
Daily UD

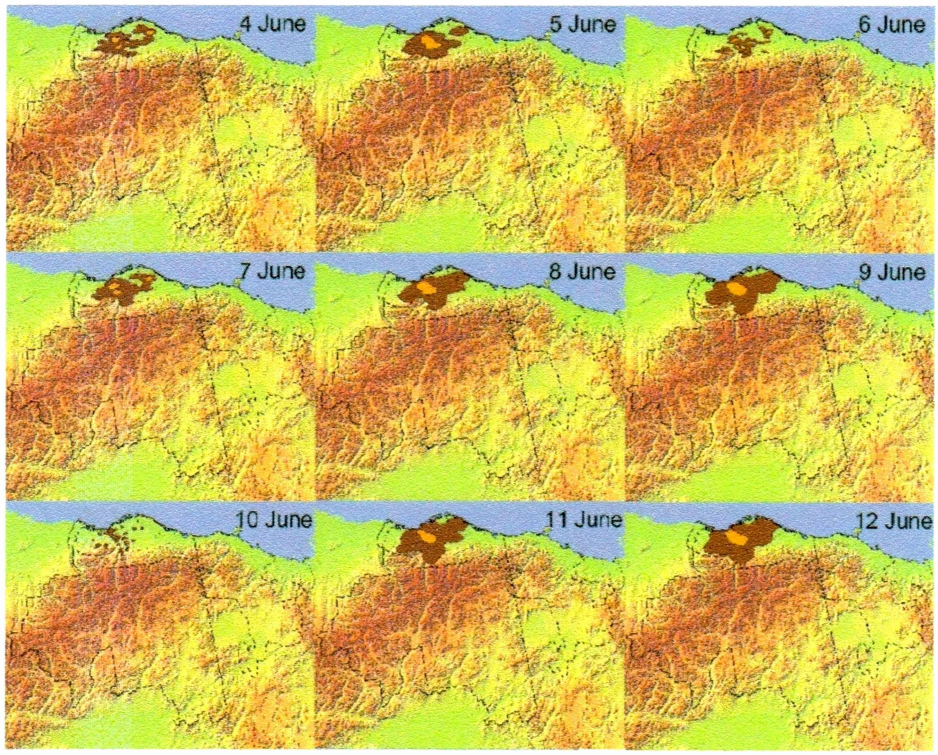


Figure B-3. 1994 Porcupine Caribou Herd (PCH) daily distributions. Brown areas correspond to the daily 99% fixed kernel utilization distribution (daily UD) of approximately 70 radio-collared calves, and the yellow areas represent concentrated use areas (CUA), where calf density was greater than average. Calves were captured within 48 hours of birth and outfitted with VHF radio collars. Weather permitting, calves were relocated daily with fixed wing aircraft.

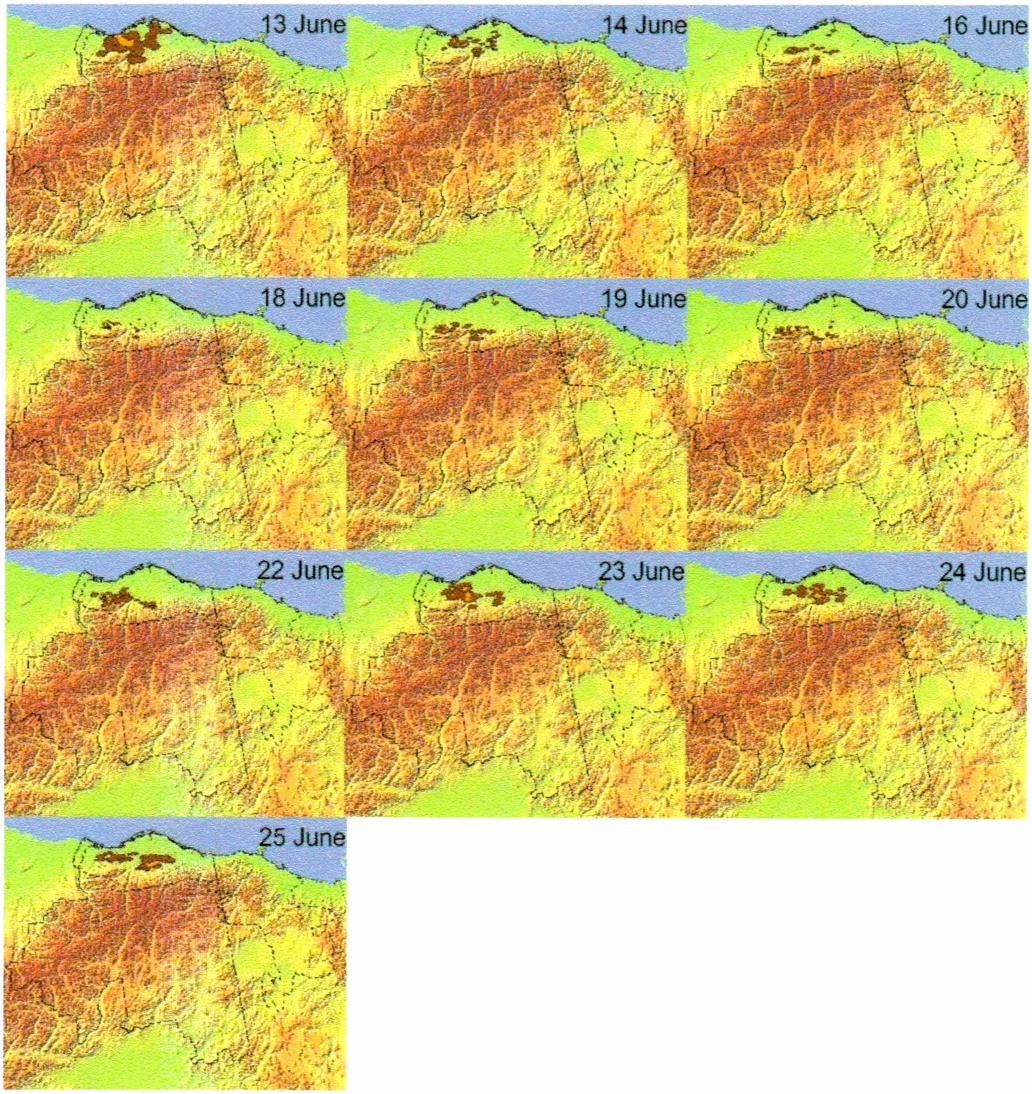


Figure B-3, continued.

Appendix C

Scatter Plots of Daily Selection Model Parameter Estimates

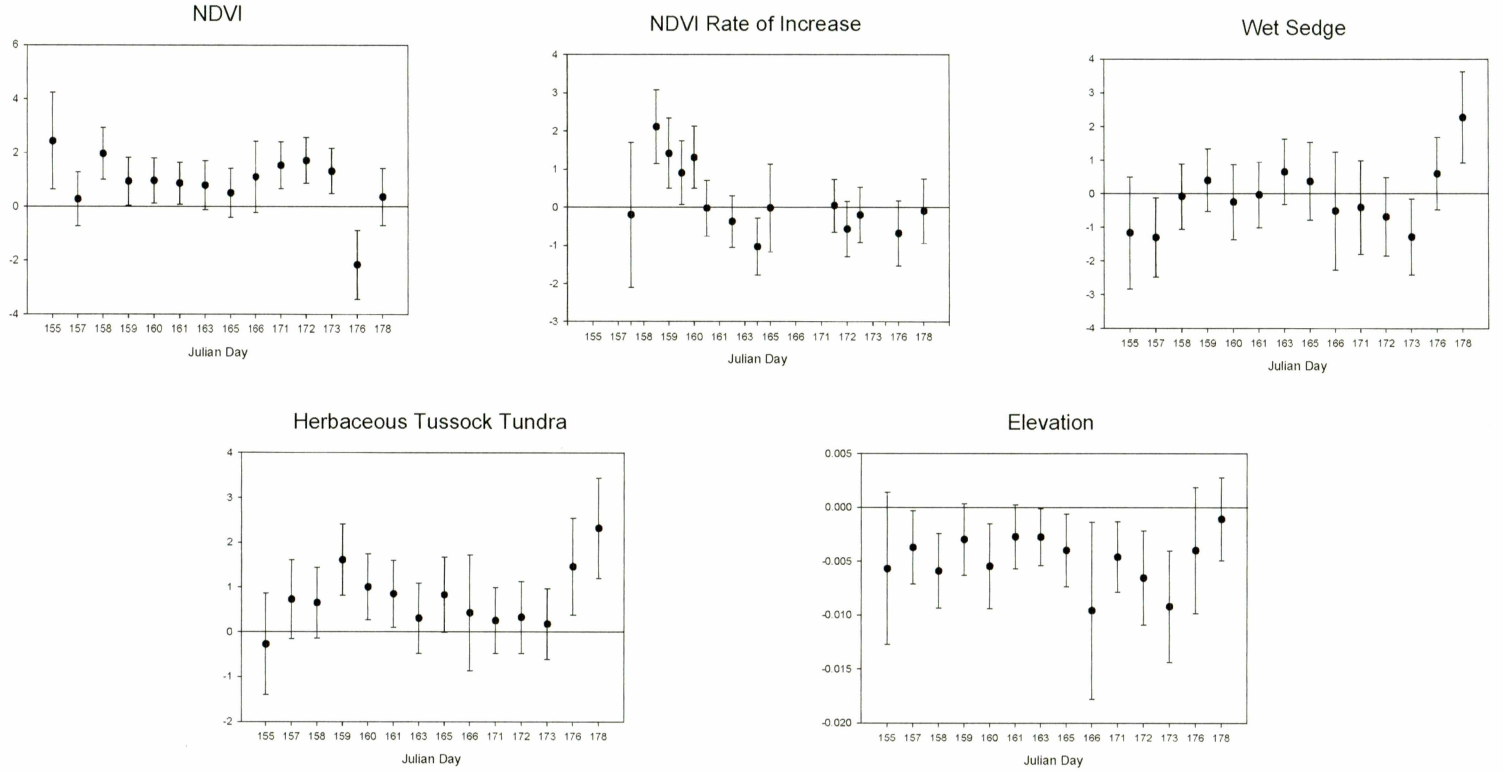


Figure C-1. Aggregate distribution scale scatter plots, 1992. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 18 to 71 radio-collared calves from the Porcupine Caribou Herd with random available points within the aggregate distribution of radio-collared calves during the 3-week calving period. The aggregate distribution was defined as the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves from the 3-week calving period.

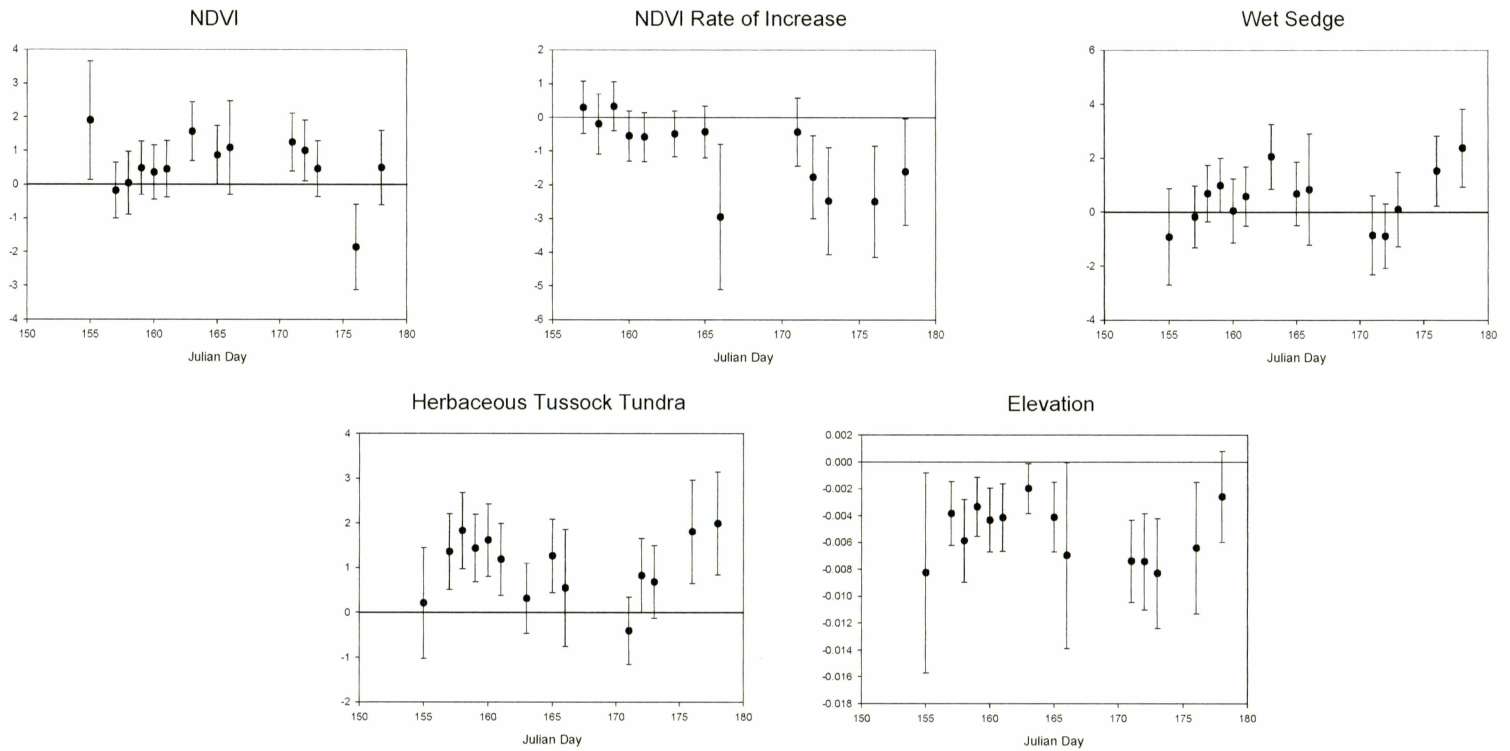


Figure C-2. Historical extent of calving scale scatter plots, 1992. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 18 to 71 radio-collared calves from the Porcupine Caribou Herd with random available points within the historical extent of calving, 1983-2001. The historical extent of calving, 1983-2001, is the merged extent of all of the annual calving grounds from that 19-year period.

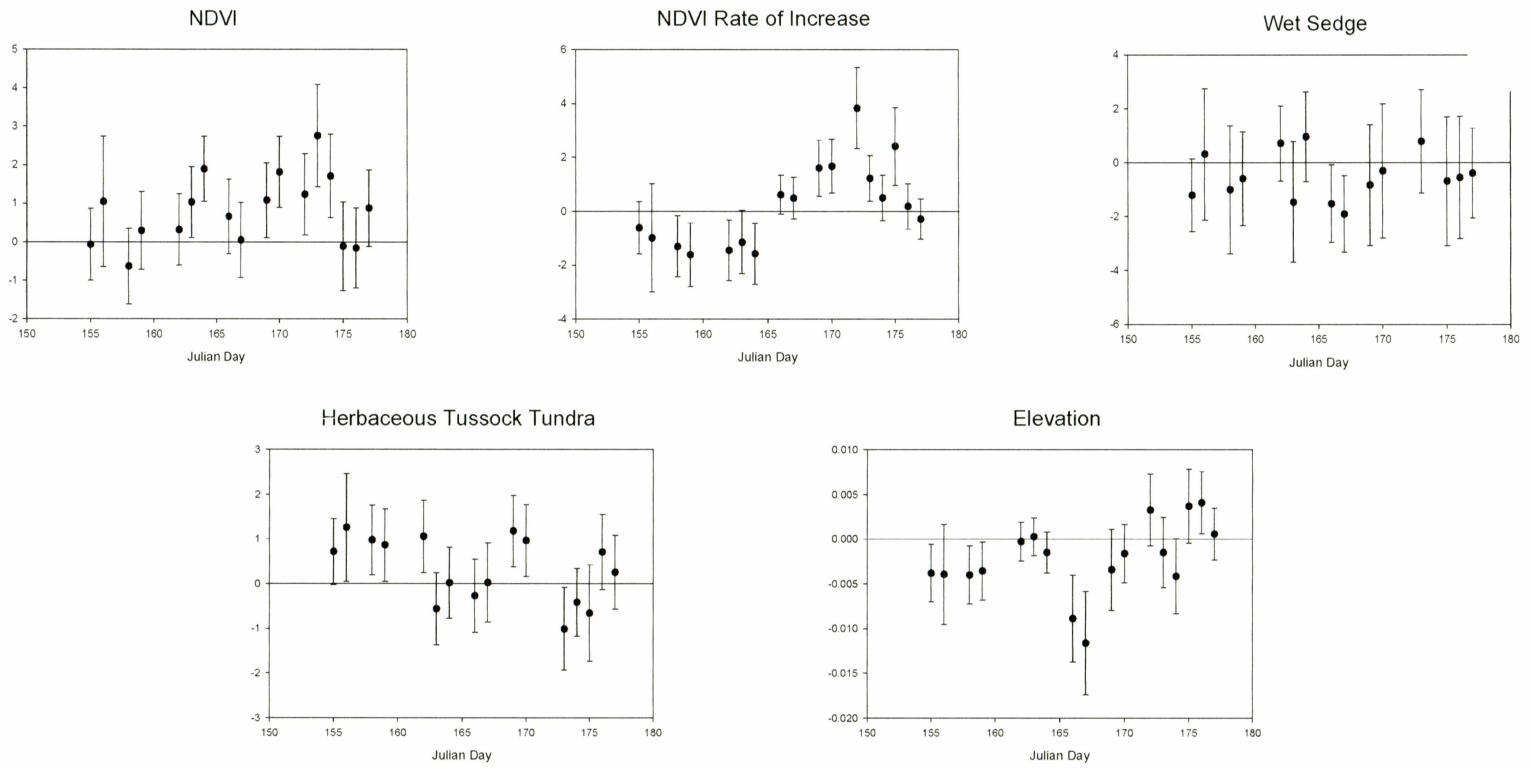


Figure C-3. Aggregate distribution scale scatter plots, 1993. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 21 to 67 radio-collared calves from the Porcupine Caribou Herd with random available points within the aggregate distribution of radio-collared calves during the 3-week calving period. The aggregate distribution was defined as the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves from the 3-week calving period.

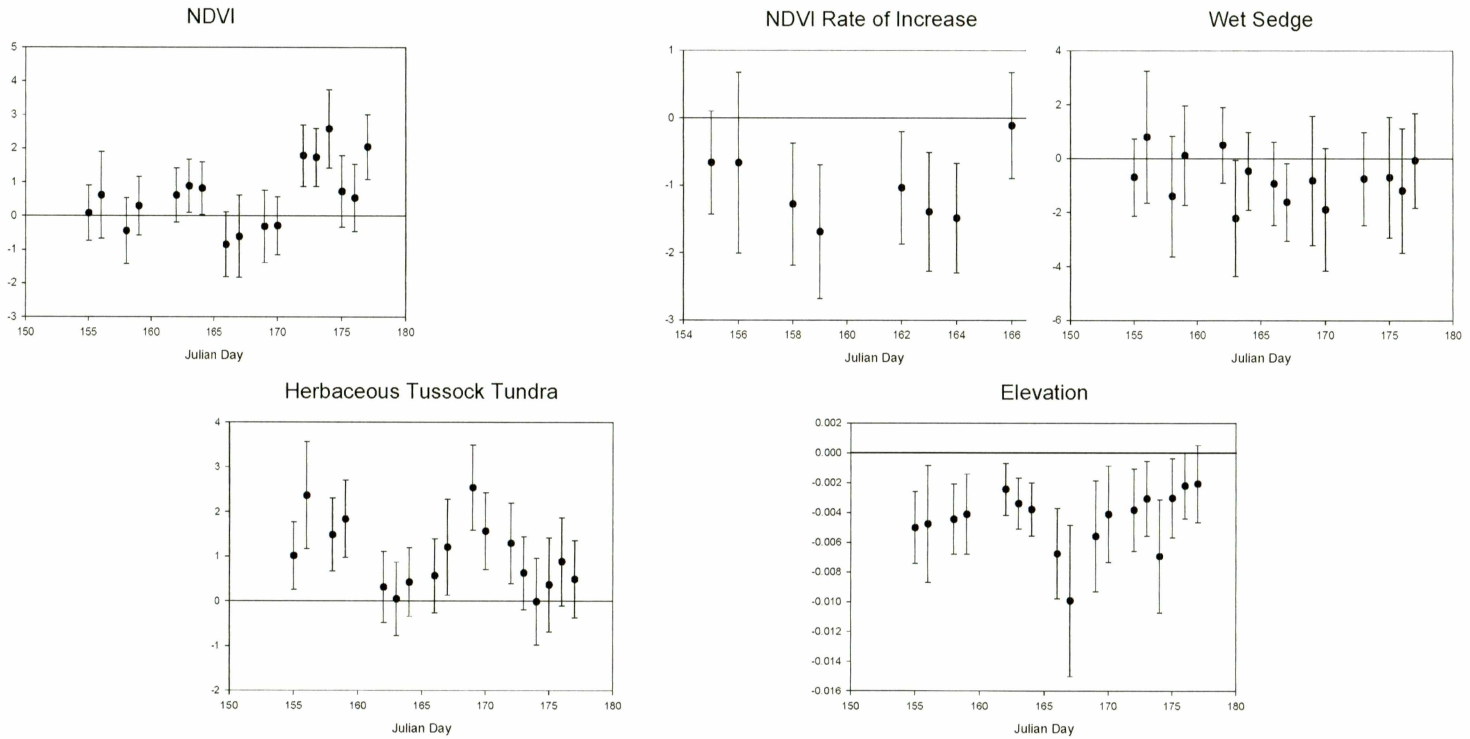


Figure C-4. Historical extent of calving scale scatter plots, 1993. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 21 to 67 radio-collared calves from the Porcupine Caribou Herd with random available points within the historical extent of calving, 1983-2001. The historical extent of calving, 1983-2001, is the merged extent of all of the annual calving grounds from that 19-year period.

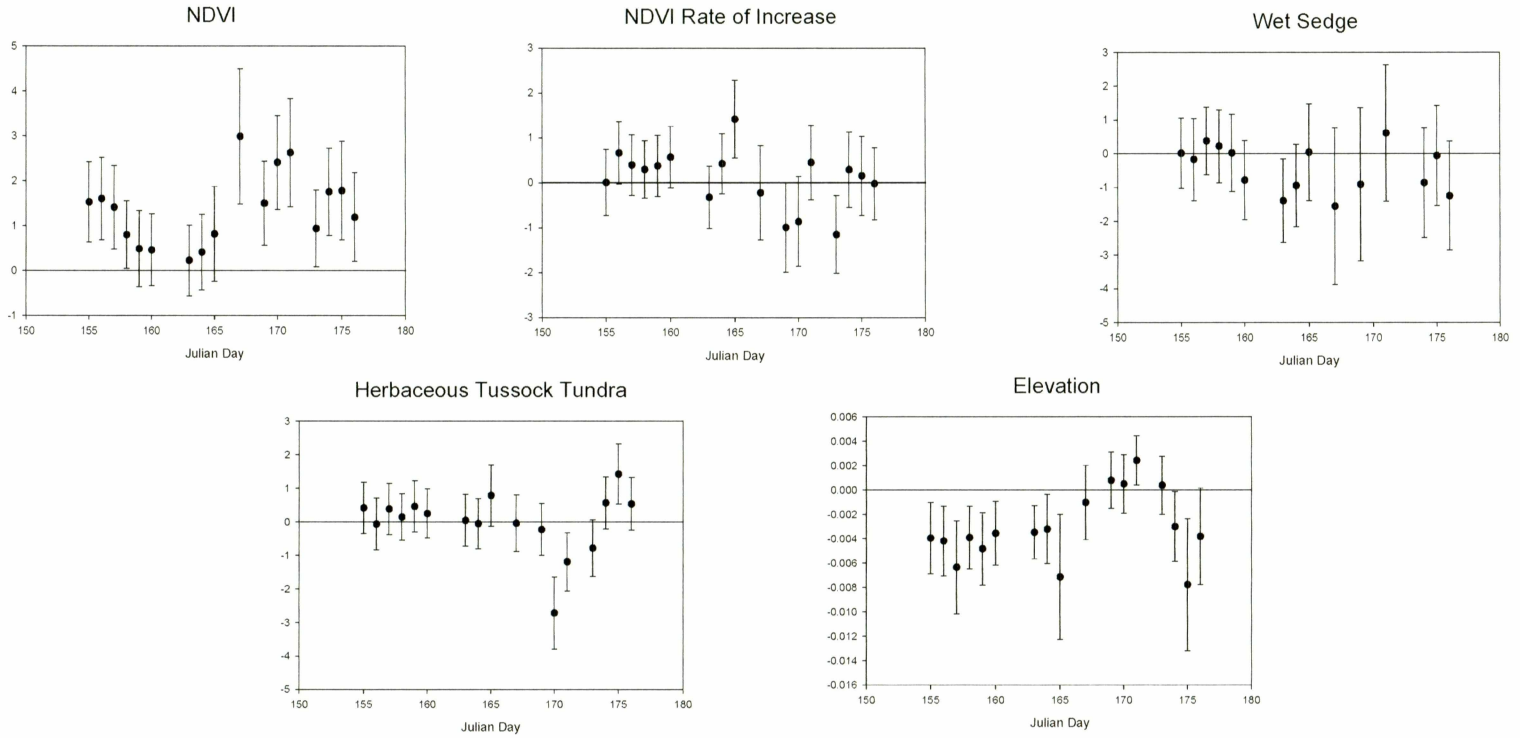


Figure C-5. Aggregate distribution scale scatter plots, 1994. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 18 to 67 radio-collared calves from the Porcupine Caribou Herd with random available points within the aggregate distribution of radio-collared calves during the 3-week calving period. The aggregate distribution was defined as the merged extent of all daily 99% fixed kernel utilization distributions of radio-collared calves from the 3-week calving period.

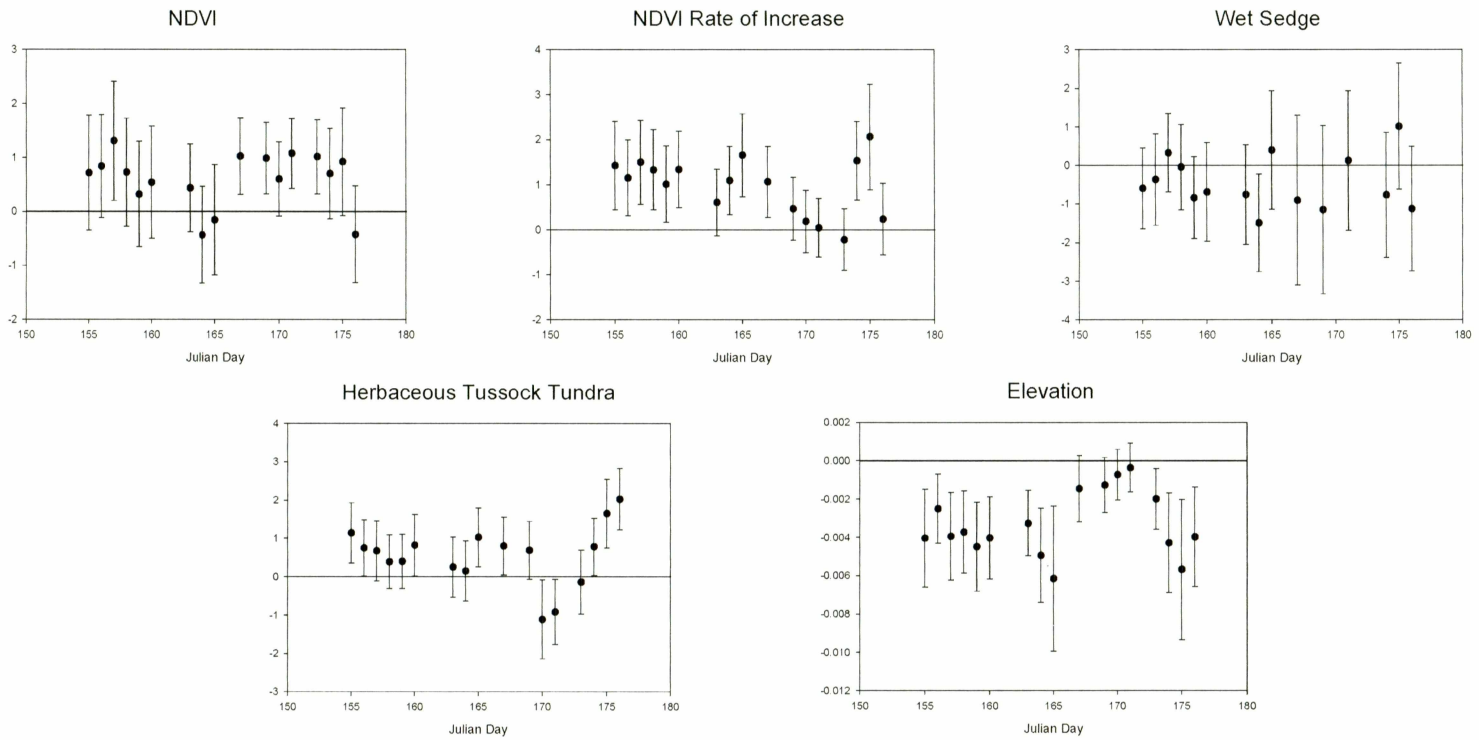


Figure C-6. Historical extent of calving scale scatter plots, 1994. Each graph is a scatter plot of daily logistic regression habitat selection model parameter estimates vs. Julian day for a given habitat variable. Selection models were built contrasting daily re-locations of 55 to 73 radio-collared calves from the Porcupine Caribou Herd with random available points within the historical extent of calving, 1983-2001. The historical extent of calving, 1983-2001, is the merged extent of all of the annual calving grounds from that 19-year period.